Waller Creek Basin Retrofit Study, An EPA Grant Project

Waller Creek photo by Scott Mittman

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Acknowledgments

Under the Assistance Agreement No. CP-996033-01-04, a part of the National Pollutant Discharge Elimination System (NPDES) Municipal Storm Water Program, the United States Environmental Protection Agency (USEPA) approved a grant application by the City of Austin (COA) staff in September 1992. Subsequently, the City Council of the COA accepted the grant in November 1992. The total grant fund was $154,000.00. The COA Drainage Utility Department's (DUD), formerly the Environmental and Conservation Services Department, grant team began the Waller Creek study in February 1993.

The current grant team, James Hubka (Data Analyst), Channy Soeur (Project Engineer), Scott Mittman (Project Planner), and George C. Chang (Project Manager) prepared this report. The team completed the grant study within the DUD's Environmental Resources Management (ERM) Division, under the general direction of Nancy McClintock, Division Manager. Although not a grant requirement, the DUD has contributed significant funds and manpower for this study.

First, the grant team would like to express deep appreciation to the USEPA for providing the unique opportunity to work in this comprehensive project. The team greatly appreciates the support provided by the USEPA grant project officers, successively, Gene Wossum, Mona Tates, Freda Wash, and Kathy Ketcher.

Further, the grant team would like to thank Melvin Hinson, former ERM Division Manager for his participation and general guidance in this project. The team would also like to thank former team members, Tom Brown, Rene Avila, John Watkins, Steve Raymond, and Suzanne Rogers for their difficult tasks in storm water monitoring, field inspection, and administrative work. The team would like to recognize Bill Burd and Richard Robinson for their efforts in processing Waller Creek data.

The grant team would like to express appreciation to the staff members in the Water Quality Monitoring Section who have assisted in this project, including Baolin Bai, Kathy Luo, Sam Mahmoud, Aboli Moezzi, Steve Manning, and to Leila Gosselink, Manager of the Watershed Management Section of the DUD, for her input and comments on the final edit of this report.

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EXECUTIVE SUMMARY

This report completes the requirements of a grant study funded by the United States Environmental Protection Agency (USEPA). The first objective of this study was to establish a storm water database for Waller Creek basin. Secondly, the study would evaluate the impact of urban development on storm water quality. Finally, the study would identify retrofit measures for the improvement of water quality in the basin, as well as in Town Lake -- the primary receiving waters. As part of the City of Austin's (COA) Storm Water Monitoring Program, the City has monitored the storm water discharges at five sites in Waller Creek basin for the past three years. With data collected from the storm water monitoring, the COA has implemented the EPA's Storm Water Management Model (SWMM) model for Waller Creek basin. The City has also developed a statistical water quality model for this basin. Through watershed simulations using these models, the City was able to estimate the quality and quantities of storm water discharges in this basin for various retrofit plan options.

The results of simulation indicate that the flood control plans specified by the studies of Chan and Loomis (see Reference List) provide some water quality benefits. As compared to the present condition, the tunnel diversion suggested by the Loomis study would not only protect the downtown area from flooding, but reduce the pollutant loads entering Town Lake by an average of about 10 percent. This reduction is due to less bank erosion between the diversion and Town Lake. The "Option 7" flood management plan (4 flood control detention basins) proposed by the Chan study for the upper watershed would reduce the pollutant loads carried by Waller Creek by about 5 percent. An alternative to the "Option 7" plan is to modify the detention ponds into dual-purpose, dry or wet ponds. This option would increase the water quality benefit to an average of about 10 percent. The channel erosion control projects recommended by these studies (that is, the repair and modification of 67 channel bank section), would likely provide good water quality benefit. This benefit can be quantified through a monitoring and modeling project.

The data presented by this study further confirms that the impact of urban development on storm water quality is two fold. The pollutants discharged from a creek generally increase with increasing urban development in the basin. In addition, the channel and bank erosion will increase with increased flow rates resulting from higher basin imperviousness. This additional erosion will increase the concentrations of pollutants in the stream. On the average, the channel and bank erosion contributed about 50% of total loads or concentrations of pollutants discharged by Waller Creek. The testing of control measures indicates that wet pond, sand filtration, and vegetated channels are efficient in detaining pollutants. Dry pond and large oil/grit separator are good pre-treatment devices. Dry or wet pond, and vegetative channels are most suitable for retrofit projects.

The database, computer models, and retrofit plan evaluations are useful for studying other urban watersheds in Austin, as well as in areas of other municipalities.

1.0 INTRODUCTION

This report characterizes storm water pollution in the Waller Creek basin (watershed) and present control measure plans to mitigate this pollution. Waller creek is a tributary to Town Lake which is a part of Colorado River. Town Lake and its upstream impoundment, Lake Austin, are typical riverine reservoirs that bisect the City of Austin (COA). The Waller Creek basin has a drainage area of 5.72 square miles. This area constitutes a fully urbanized basin (Figure 1, Waller Creek Basin Location Map). The existing urban development in the basin is likely impacting the storm water quality of Waller Creek, and in turn, increasing the pollution of Town Lake. It has been perceived by the City that the existing storm water quality condition of Waller Creek should be quantified and that efforts should be made to improve this water quality condition.

1.1 Objectives of Study

The purpose of this study is to evaluate the effect of storm water discharges on the targeted urbanized basin and subsequently identify innovative storm water control measures for improving water quality throughout this basin, as well as in Town Lake, the receiving water body. The specific objectives of this study are:

- to monitor and establish a storm water discharge database for the Waller Creek basin,
- to evaluate and quantify the effectiveness of various storm water control measures,
- to develop demonstration computer models in order to quantify and generalize basin storm water quality condition, and to evaluate the impacts of control measure plans on basin water quality conditions,
- to recommend basin storm water quality and quantity retrofit plans, and
- to provide useful technical guidance to other municipalities that undertake such retrofit programs within their urban core.

1.2 Background of Study

The Waller Creek basin Retrofit Study is an U. S. Environmental Protection Agency (USEPA) grant project under the National Pollutant Discharge Elimination System (NPDES) program. Based on the needs of the COA Urban Watershed Retrofit Program (COA, 1992 - 2 reports), the City applied for and obtained this grant project in late 1992.

In late 1986, the COA established the Comprehensive Watershed Ordinance (CWO) (COA, 1987) in order to protect water quality in the developing watersheds, following a period of rapid urban growth. The CWO, however, generally excluded the urban core watersheds from its water quality provisions and land development controls. With increasing concerns that the lack of efforts and regulation in urban watersheds and Town Lake would lead to unremediable problems, the City revised the CWO and implemented an Urban Watershed Ordinance in 1991 (COA, 1991). In connection with this ordinance,

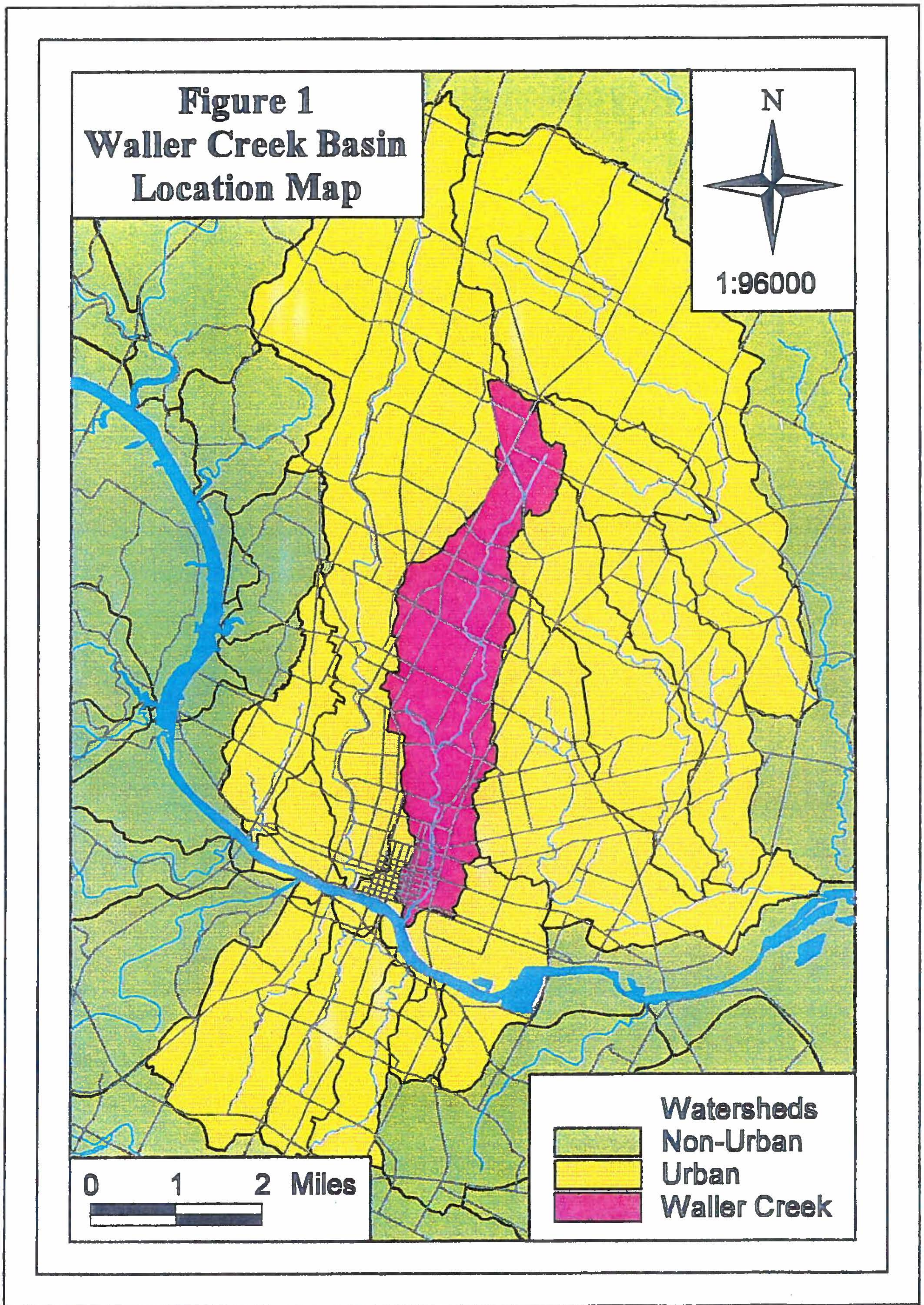


Figure 1
Waller Creek Basin
Location Map
N
1:96000
Watersheds
Non-Urban
Urban
Waller Creek
0 1 2 Miles

the City has instituted significant efforts to manage and retrofit the water quality and flood control conditions of the urban watersheds. The planning portion of the efforts was to develop basin drainage master plans for these watersheds.

This grant study provides basic data and a modeling tool for developing master plans of the Waller Creek basin and other urban watersheds. In addition, this study is recommending watershed retrofit plans for the Waller Creek basin.

1.3 Scope of Study

This study consisted of five components: storm water monitoring, control measure study, watershed modeling, cost and benefit evaluation of retrofit plans, and technology transfer. This study covered the entire Waller Creek basin and lasted about three years, including 2-3 years of monitoring work. The monitoring project established 5 storm water monitoring sites, with 2 in-stream stations and 3 small structural Best Management Practice (BMP, i.e., control measure) sites. These sites are also a part of the current COA's Storm Water Monitoring Program (SWMP) which has, over the years, monitored 67 monitoring stations at 43 sites. The control measure study used data collected from many BMP sites in the SWMP network. In order to evaluate the basin-wide runoff and water quality conditions, this Waller Creek study adopted the USEPA's Storm Water Management Model (SWMM) (EPA, 1987) for watershed runoff simulation. The study also developed a statistical model to quantify the pollution associated with the storm water runoff. Based on the watershed simulation using these models for different control measure conditions, the study evaluated and recommended retrofit projects. The selection considered the benefits and costs for each retrofit plan.

Quantified data and information derived from this study are useful in developing drainage master plans for the COA's Urban Watersheds. Furthermore, most of these data and information are related to specific BMPs and to general basin characteristics such as land-use types, channel conditions, and impervious cover percentages. They are valuable in studying watersheds and developing basin management plans for other municipalities or metropolitan areas.

2.0 DESCRIPTION OF WALLER CREEK BASIN & RELATED STUDIES

This section of the report describes the Waller Creek basin, its problems, existing data, and the related studies.

2.1 Morphology

The Waller Creek basin is a fully urbanized watershed (about 98 percent developed), located at the central part of the COA. The watershed is oriented generally in a north-south direction from the intersection of North Lamar Boulevard and U. S. Highway 183 to Town Lake (Figure 1, Waller Creek Basin Location Map). The topography of the watershed is gently rolling to moderately sloping in the lower end of the basin. The average slopes of the upper and lower lands are about 2.2 and 4.1 percents, respectively. With its headwater at the top of the watershed, the Waller Creek extends from north to south, entering Town Lake at a point about 0.75 mile upstream from Longhorn Dam. The total length of the main stream of Waller Creek is about 6.6 miles. The creek is generally a tree-lined natural channel. Dense stands of small trees and brush are common along the creek. Many reaches of the creek show thick rock outcrops which line the channel and banks. Some cleared areas along the bank, however, are lacking vegetative cover and are subject to severe erosion. The average channel slope of the creek is about 0.8 percent. The major tributary to Waller Creek is Hemphill Branch, which connects to the storm sewer system at 33rd Street and enters Waller Creek below 26th Street near San Jacinto Boulevard. The upper portion of Hemphill Branch is lined with stone and mortar walls whereas most of the lower segments contain natural channel, covered with substantial vegetation.

2.2 Land-Use and Impervious Cover

For the COA, the Waller Creek basin is also the center of many cultural and political features that include the University of Texas, the State Capitol, St. David's and Brackenridge Hospitals, the Convention Center, and a major portion of downtown Austin. About 24 percent of the area in the basin is civic or educational land-use. The land-use of the upper end of the basin (above RR 2222) is mixed, but the area consists of 50 percent single family (SF) residential land-use. The middle portion (between Martin Luther King Boulevard and RR 2222) is dominated by residential, civic, and educational land-uses. The lower segment (below MLK Boulevard) is characterized by the state office complexes, and the downtown office and commercial areas. Roadway constitutes about 5 percent of the basin area. Table 2.1 and Figure 2 provides a quantified distribution of land-uses for the Waller Creek basin.

The distribution of impervious cover in the basin is shown in Figure 3. For each land-use in the basin, there is a corresponding value of area-weighted average of impervious cover percentages. This relationship between land-use and impervious cover percentage is shown in Table 2.1.

Table 2.1
Land-Use and Impervious Cover Distribution

Land-Use	Total Area Acres	Total Area Percent	Impervious Area Acres	Impervious Area Percent of Total Basin Area	Impervious Cover Percent for Each Land-Use
Single Family Res.	1302	36.3	494	25.2	38.0
Multi-Family Res.	223	6.2	161	8.2	72.3
Commercial	377	10.5	331	16.9	87.7
Office	260	7.3	204	10.4	78.2
Industrial	129	3.6	80	4.1	62.3
Civic/Education	915	25.5	502	25.6	54.8
Open Space	125	3.5	14	0.7	10.9
Transportation	162	4.5	152	7.7	93.7
Utilities	8	0.2	5	0.2	56.7
Undelveloped	89	2.5	16	0.8	18.5
Total	3591	100.0	1959	100.0	54.6

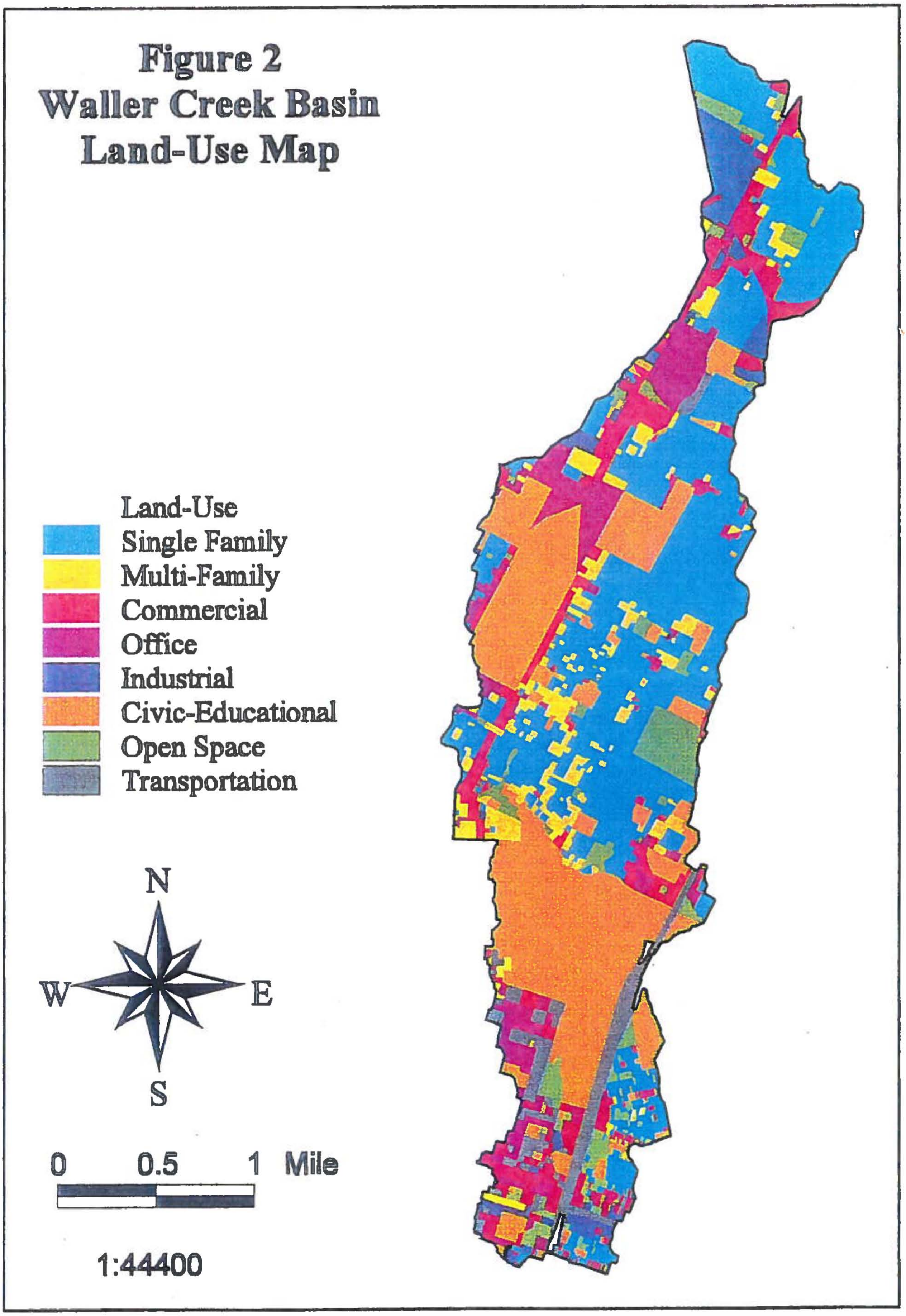
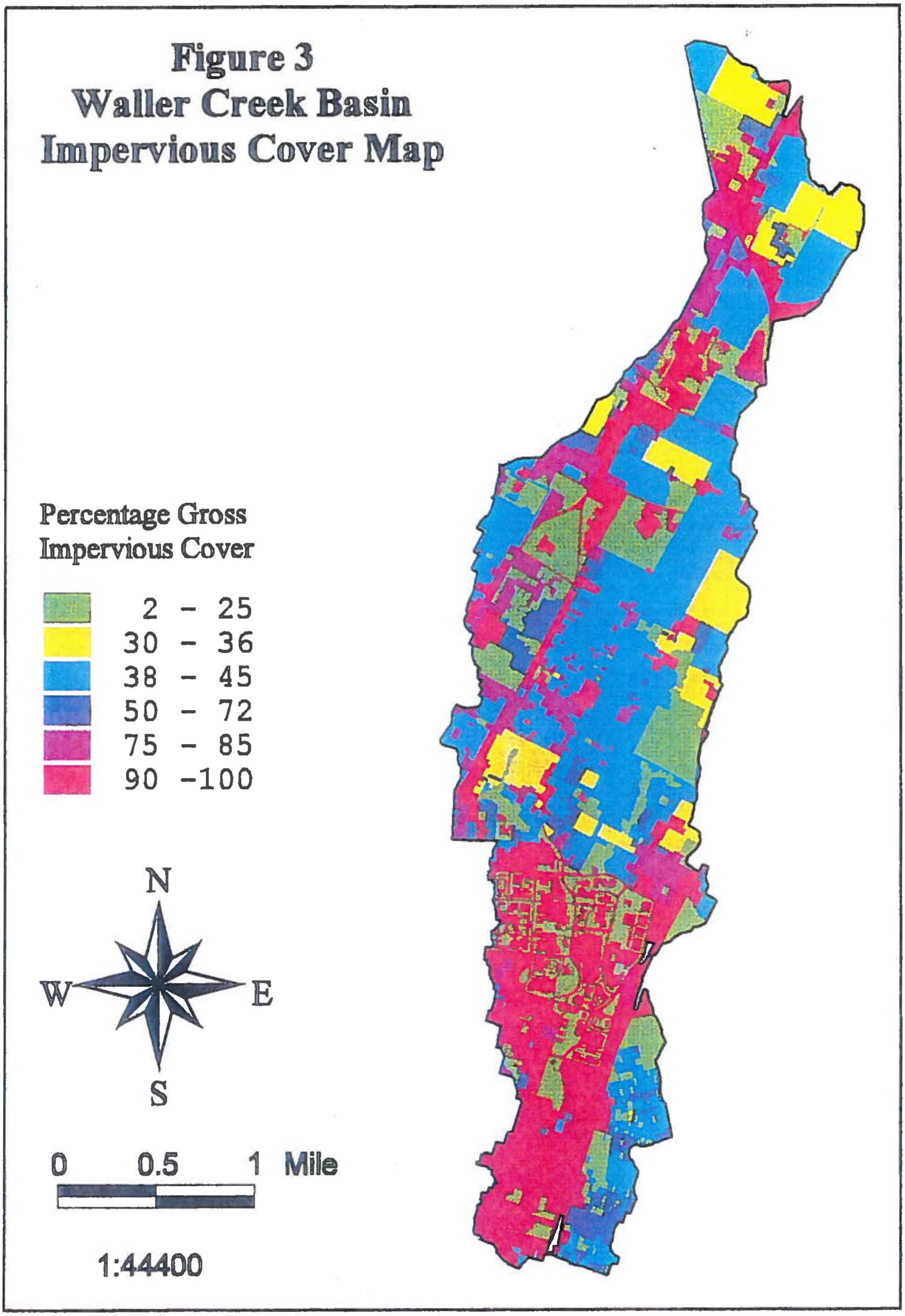


Figure 2
Waller Creek Basin
Land-Use Map
Land-Use
Single Family
Multi-Family
Commercial
Office
Industrial
Civic-Educational
Open Space
Transportation
N
W
E
S
0
0.5
1 Mile
1:44400

Figure 3
Waller Creek Basin
Impervious Cover Map



2.3 Available Hydrologic Data

Very little storm water quality data of the Waller Creek basin existed before this grant study. The U. S. Geological Survey (USGS) conducted periodic water quality surveys at Waller Creek @ 23rd Street before 1970 and presented data of primarily baseflow concentrations. The USGS (USGS/COA, 1975-81) also measured the streamflow of Waller Creek during 1955-81 at two in-stream gauging stations. Daily streamflow records of the two stations for this period are available. A corresponding daily rainfall record for the period of 1976-81 is also available.

Starting in 1986, the COA Public Works Department established a network of rainfall gauges and flow level sensing devices in the Austin area under the Flood Early Warning System (FEWS) Program. Nine rainfall gauges located within or near the Waller Creek basin provide a continuous rainfall record for this study.

2.4 Impoundment and Baseflow in the Waller Creek Basin

A wet pond for flood control and water quality control at 38th Street and Guadalupe Street is near completion. This pond controls 156 acres in the Hemphill Branch of Waller Creek. A few more water quality basins were built, in recent years, in order to comply with the City's requirements for new development in the urban watersheds. There are no significant impoundments existing in the basin, with the exception of some flood control detention ponds that exist to control small areas in the Waller Creek basin.

A small reservoir was created in Waller Creek at about 41st Street. The culverts under the dam, however, allow streamflow to continuously pass through downstream. A large depressed area near the School of the Blind, in the Hemphill Branch of Waller Creek, impounds the drainage of about 93 acres. The impact of impoundment on the volume and flow rate of streamflow is minor (estimated to be within a few percent of the total flow).

On an annual basis, baseflow in Waller Creek constitutes about 15 to 25 percent of the total streamflow. Baseflow is mainly the recharge or reoccurrence of water infiltrated into the ground. There are probably springs located north of 38th Street that recharge to the stream. Some tap water drained from the municipal and private swimming pools also enters Waller Creek. As compared to the storm water, the impact of baseflow on the water quality of Waller Creek is minor.

2.5 Soils and Geology

The Waller Creek basin is part of the Blackland Prairie vegetated area. To the west of the basin it is the Edwards Plateau. Waller creek passes through two major bedrock units. In the south end the creek lies in beds of unconsolidated sand and gravel alluvium. The remaining portion of the creek (reaches upstream from the 7th Street except the upper end of the creek) has mostly a creek bed of soft limestone. The banks of the lower and upper ends of the creeks are composed of dirt and gravel. The banks of the middle sections contain exposed limestone.

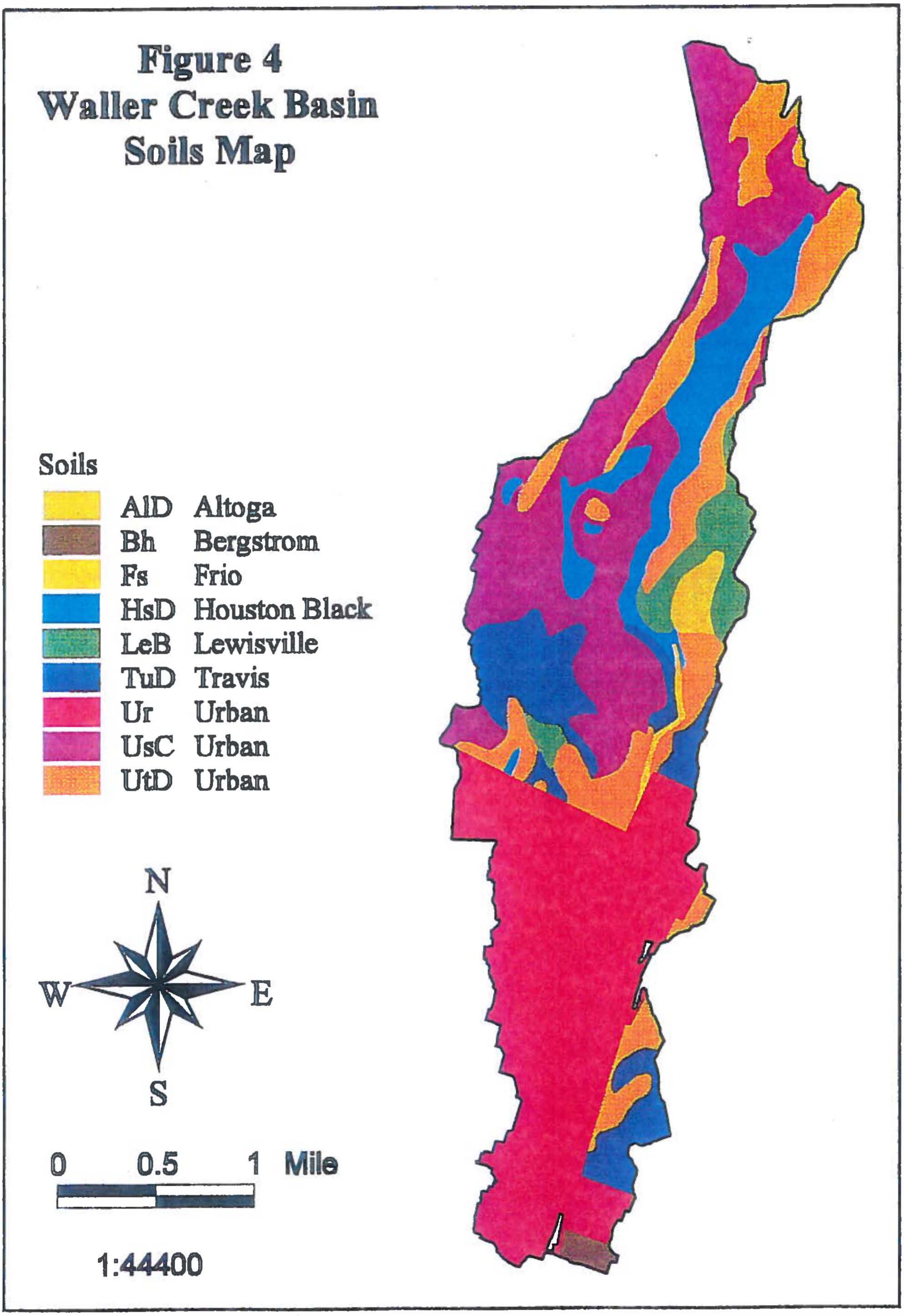


Figure 4
Waller Creek Basin
Soils Map
Soils
AlD Altoga
Bh Bergstrom
Fs Frio
HsD Houston Black
LeB Lewisville
TuD Travis
Ur Urban
UsC Urban
UtD Urban
N
W
E
S
0 0.5 1 Mile
1:44400

Soils in the Waller Creek basin are mainly clay, which include Urban, Houston Black, Travis, and Brackett soils. These soils have low permeability, high erosion potential, and shrink-swell problems. Most of these were classified by the U. S. Soil Conservation Service as Type C soils (except Houston Black which is Type D) and are known to have high runoff potentials. However, soils in the Waller Creek basin have been so altered by urban development, that they may no longer resemble natural soil associations in the area.

Figure 4 shows the distribution of soil types in the Waller Creek basin.

2.6 Related Studies

This report used data collected from the Waller Creek basin monitoring project. Additional data and information were obtained from the previous and on-going COA and its related studies. The COA currently has a Storm Water Monitoring Program (COA, 1996) and a USGS/COA Cooperative In-Stream Monitoring Program which have established a network of storm water monitoring sites. The City has been preparing a characterization report (COA, 1995) which presents storm water data of 41 monitoring stations at 34 sites. This report provides storm water runoff and runoff pollutant concentration data and their relationships with land-use type, development condition, size of drainage basin, and various types of control measures. A previous COA study (COA, 1990) evaluated the treatment efficiency of water quality control ponds such as sedimentation and filtration basins, and wet ponds.

The COA has ambitious goals to manage and re-develop the Waller Creek basin. The City successively hired engineering consultants to study and develop strategies for managing flood, channel erosion, and water quality conditions. Chan and Associates (Chan, 1995) identified the existing and potential flooding and erosion problems along Waller Creek and developed the corresponding corrective measures for the problem areas. The study proposed several options of control methods for consideration. These options were further reviewed to result in a final plan which consist of the implementation of 4 flood control detention basins and the improvement of some sections of channels and culverts. Based partially on the results of this flood management study and data generated from the COA's Waller Creek grant project (data of this report), Loomis and Associates (Loomis, 1996) prepared a report concerning flood management and water quality improvement in the downtown Waller Creek watershed. This report is Phase I of a proposed three phase project which will provide planning and engineering design for flood control measures in the downtown area and for basin-wide water quality enhancement. The phase I study recommended an 18 to 20-foot diameter, 5,500 feet long flow diversion tunnel for flood control and in-stream erosion control and various structural and non-structural BMPs for basin-wide water quality enhancement.

The COA has adopted EPA's SWMM for basin-wide storm water runoff and water quality studies. The COA applied SWMM to the City's Barton Creek basin (COA, 1995) which has a drainage area of about 120 square miles. The basin is mostly undeveloped but it has been under tremendous demands for urban development. The COA researched SWMM's capabilities and found that the SWMM is very powerful for conducting basin-wide continuous simulation on storm water runoff and channel flows. Nevertheless, it was discovered that it is very difficult to apply SWMM's water quality program (the build-up and wash-off process algorithm) to a watershed. It was determined that the modeled time series of the build-up and wash-off process cannot be verified unless there is detailed storm rainfall-runoff and water quality data such that a reliable build-up model can be established and that the watershed wash-off can be quantitatively separated from the channel erosion process. The COA may have these data when the City's overall Storm Water Monitoring Program approaches completion. It is doubtful, however, that there is such detailed data available in any other regions.

3.0 STORMWATER MONITORING PROGRAM FOR WALLER CREEK

In order to evaluate the existing storm water quality conditions and the effectiveness of specific structural control measures, the COA established 7 storm water monitoring stations at 5 sites (or locations) within the Waller Creek basin. Figure 5 shows the locations of the monitoring sites. Table 3.1 provides a brief description of these monitoring sites. The COA staff used data collected from these sites as well as the other COA monitoring sites for this report

3.1 General Description of COA Storm Water Monitoring Stations

All of the COA storm water monitoring stations are remote-controlled flow measuring and sample collection facilities/systems. As shown in Figure 6, a remote-controlled stormwater monitoring system consists of several components such as flow meter(s), flow meter sensing device (bubbler tubes, pressure probe, or ultrasonic sensor), automatic water quality sampler(s), hose and strainer for sampling, rain gauge, batteries (or AC power), solar panel, alarm system, equipment shelter, a flow measurement structure, and an access to the station. The flow meter is connected and tripped by its sensor to record the depths of water in the channel. The meter will also convert depth readings to flow rates if a flow rating equation (rate of flow versus depth of flow relationship) can be established.

The COA usually installed a flow measurement structure such as a weir or flume to establish such equation. In some cases, the staff conducted hydraulics modeling studies or on-site flow calibrations (during storm rainfall events) to derive a flow rating equation. The flow meter has a data logger which stores and transmits flow data to a computer in the office through a telephone line. The water quality sampler can be run to collect water samples at intervals of equal time or flow volumes through the operation of the flow meter. The entire flow monitoring operation can be remotely controlled through the office computer. Nevertheless, the water samples have to be picked up from the monitoring site, preserved, and send to the laboratory for analysis. Sample bottles should be iced and equipment be checked before an expected rainfall event. Equipment and flow measurement area should also be maintained periodically.

3.2 In-Stream Storm Water Monitoring Sites

The COA has two storm water monitoring stations along Waller Creek, one at 38th Street and another at 23rd Street (see Figure 5). Before 1981 the USGS operated two streamflow gauging stations at these locations. The USGS measured gauge heights of flow from a reference point on the top of a concrete, broad crest weir. Corresponding to some of the gauge height measurements, the USGS measured flow rates at a cross section under a bridge downstream from the weir. The USGS correlated flow rate and gauge height readings and developed flow rating curves (relationships) for these two in-stream stations. These relationships should still be valid in consideration of the lasting stability of the concrete weir and banks along the channel sections. These relationships can be used to convert flow level readings to rates of flow for each storm rainfall event. The COA installed a remote-controlled storm water monitoring station at 38th Street in September 1992 and at another station at 23rd Street in 1993. The City continuously measured storm

Table 3.1
Storm Water Monitoring Sites in Waller Creek Basin

Station ID	Monitoring Site/Location	Site Type	Drainage Area (Acres)	Landuse	Impervious Cover (%)	Type of BMP
W8A	Waller Creek @ 38th St.	In-stream	1416	Mixed	47	None
W3A	Waller Creek @ 23rd St.	In-stream	2643	Mixed	49	None
WDI	45th St. @ Duval Blvd.	Auto-repair/Storage	0.1	Ind/Com	99	O/G Separator (L)*
WDE	45th St. @ Duval Blvd.	Auto-repair/Storage	0.1	Ind/Com	99	Bmp Outflow
WCI	Convention Center @ 2nd St.	Downtown	35	Com	99	O/G Separator (S)
WCE	Convention Center @ 2nd St.	Downtown	35	Com	99	Bmp Outflow
W5A	5th St. @ Red River St.	Downtown	3	Com	95	Street Inlet Filter

* O/G Separator (L) - Large Separator
O/G Separator (S) - Small Separator

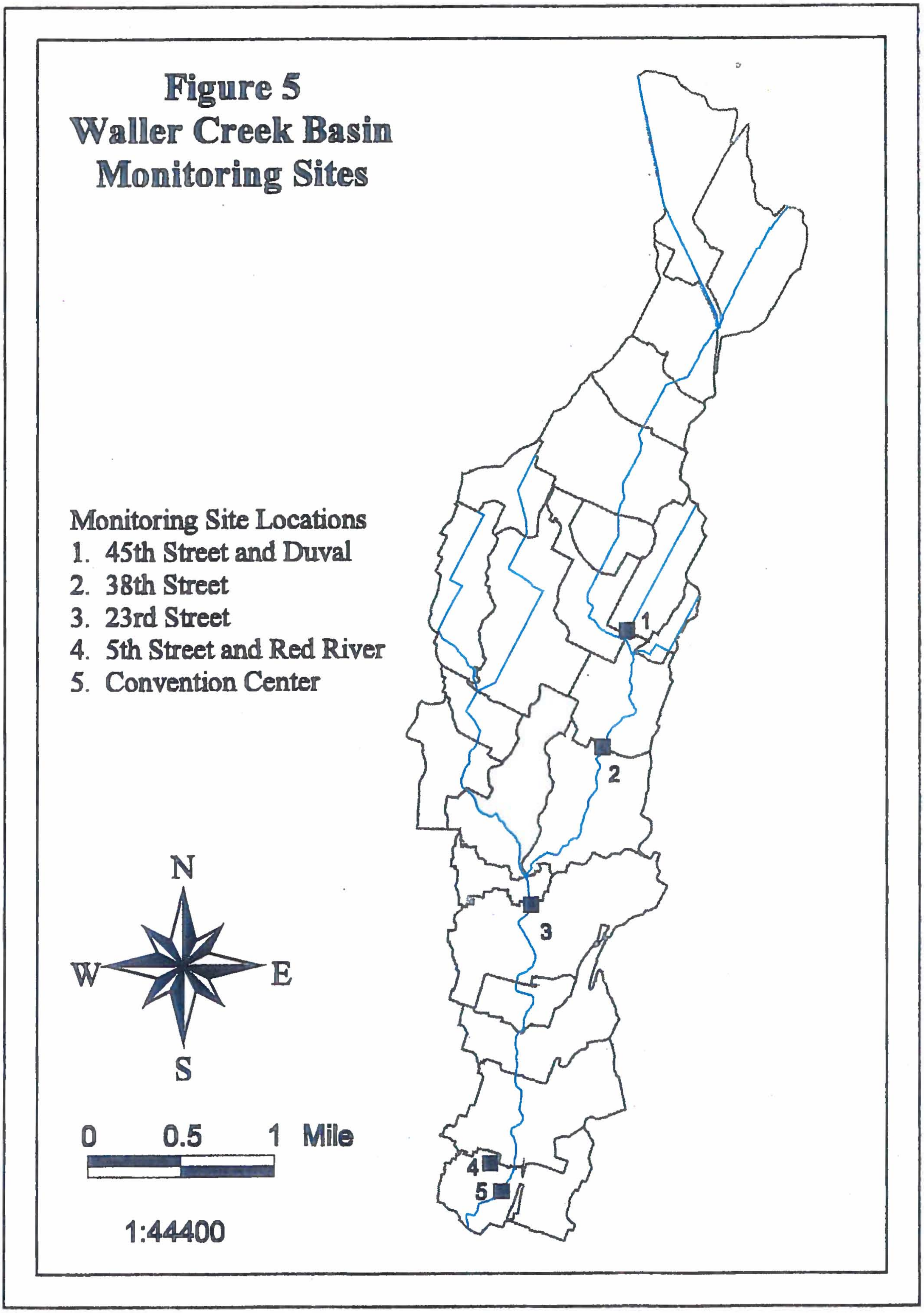


Figure 5
Waller Creek Basin
Monitoring Sites

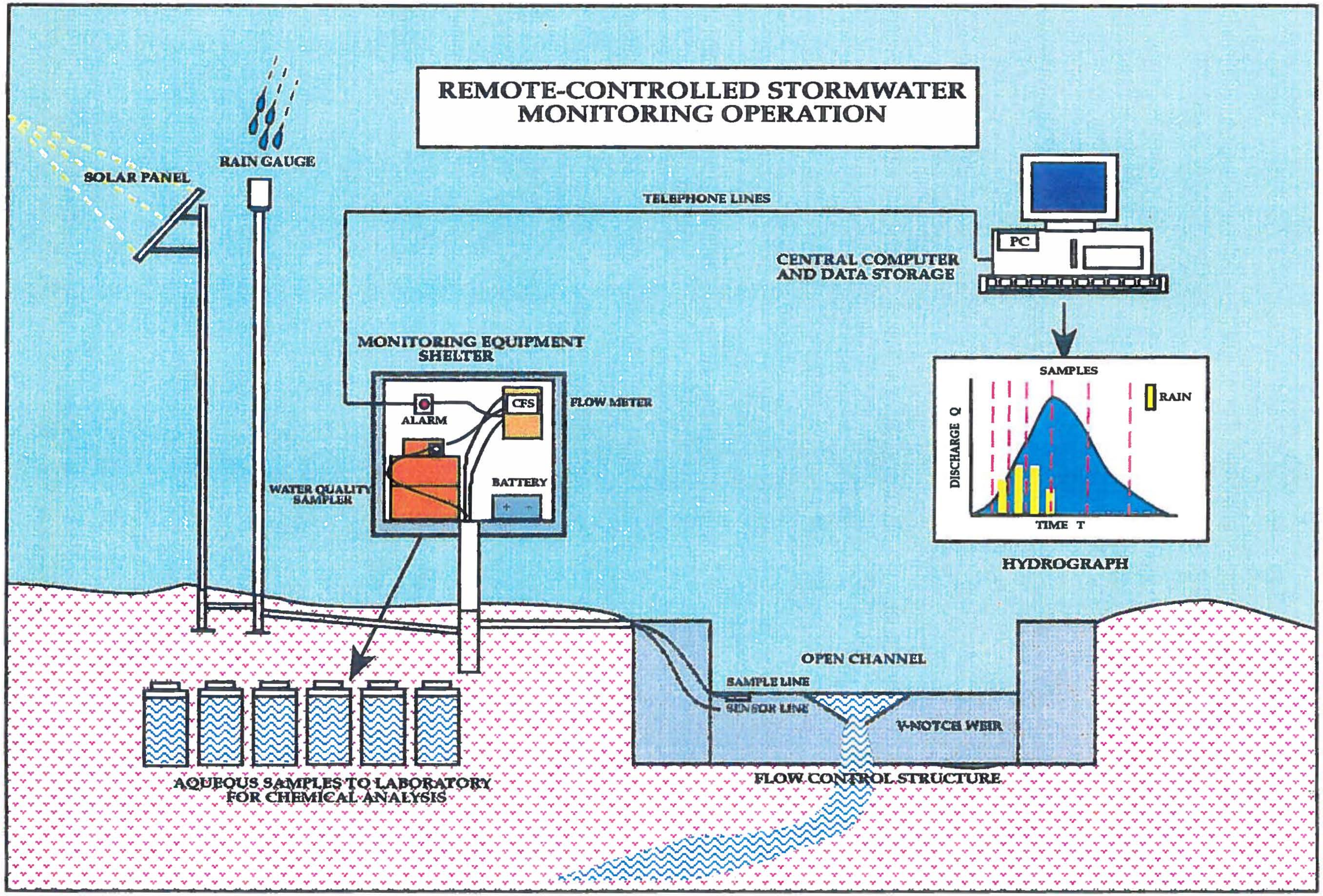


Figure 6. Remote-Controlled Stormwater Monitoring System

continuously measured storm water runoff discharges passing through these stations. The City also sampled the discharges at each of the stations for 22 rainfall events. Through measurement and sampling activities through these events, the City established the in-stream, storm water discharge and pollutant concentration data files for Waller Creek. This report used these data to develop and calibrate SWMM and the statistical water quality model.

These data were further processed to give watershed mean concentration values, as presented in Tables 3.2 and 3.3. The COA studied and concluded that the storm water mean pollutant concentrations for a watershed generally depend on basin development condition and size of the watershed. A development condition can be identified by the basin's "percent impervious cover" or by a "development index" which represents a combination of several factors such as land-use type, age of infrastructures, traffic density, and the degree of housekeeping practice. Quantitatively, the development index is the arithmetic mean of land-use type index and watershed-type index. Land-use type index is a value of 1.0 to 5.0, corresponding to 5 land-use types, i.e., undeveloped, single-family residential, multi-family residential/office, commercial/industrial, and transportation (UNDEV, SFR, MFR/OFFI, COMM/INDU, and TRAN). Watershed type index is a value of 1.0 to 3.0, corresponding to 3 watershed types, i.e., urban, suburban, and rural. Table 3.4 presents equations relating watershed mean concentrations with basin development conditions and drainage areas.

3.3 Testing of Oil and Grit (O/G) Separators

Since September 1993 the COA has begun to test the effectiveness of small control structures such as O/G separators and street inlet filters. In late 1994, the COA installed 2 sets of inflow-outflow storm water monitoring stations to monitor 2 O/G separators, one at 45th Street @ Duval Boulevard and the other at the City's Convention Center. The O/G separator at 45th Street receives storm water drains from a gas station-converted auto repair and storage facility. The separator has a typical design which provides a 2-chamber settling box of about 30 cubic feet capacity. The City built a circular ramp at the inlet of the separator in order to collect storm water samples during storm rainfall events. At the outlet the City constructed a rectangular channel and a V-Notch weir to measure flows and to collect water samples. Up to August, 1995, the City has monitored the structure for about 10 storm rainfall events. The pollutant concentrations of the storm water discharges from this site are generally similar or higher than those of the City's average commercial/industrial sites. On the other hand, the O/G and TPH (total petroleum hydrocarbon) concentrations of the discharges are mostly below detection limits.

Based on the paired comparisons of mean concentrations between inflows and outflows, the structure shows little treatment efficiency in retaining pollutants. The lack of treatment is likely due to the fact that the storage of the separator is too small to provide minimum detention time for the pollutants to settle. Nevertheless, this type of separator should be effective in detaining pollutant spills during dry days when there are no storm rainfall events.

Table 3.2
Mean Concentration Values For Waller Creek -- Site ID W8A

Site Name:	Waller Creek @ 38th Street
Drainage Area:	1,416 acres
Land-Use Type:	Mixed
Impervious Cover:	47%

Pollutant Parameters	All Events 23 Observations			Small Events * 14 Observations				Large Events 11 Observations			
	VWM **	Mean	Median	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
TSS	731.6	401.2	215.0	136.1	67.8	2.8	585.6	813.5	776.3	215.0	1414.5
BOD	12.81	15.37	10.11	17.80	9.44	3.91	76.00	12.13	13.51	6.00	17.31
COD	106.2	87.5	78.7	70.1	50.0	6.0	197.0	111.2	119.0	64.0	167.2
TOC	9.44	9.90	8.81	10.34	9.14	4.62	18.62	9.32	8.81	7.47	13.50
NO2+NO3	0.613	0.845	0.611	1.038	0.817	0.178	3.625	0.554	0.509	0.093	1.633
NH3	0.241	0.215	0.172	0.194	0.139	0.046	0.576	0.248	0.227	0.087	0.506
TKN	2.863	2.284	2.657	1.747	1.087	0.274	4.437	3.016	3.009	1.840	4.244
TN	3.423	3.076	3.187	2.785	2.100	0.557	7.148	3.511	3.544	2.171	4.827
TP	0.872	0.644	0.509	0.432	0.322	0.185	1.033	0.933	0.990	0.437	1.606
Cu	0.0209	0.0169	0.0150	0.0117	0.0100	0.0035	0.0200	0.0221	0.0246	0.0100	0.0361
Pb	0.0662	0.0514	0.0485	0.0319	0.0332	0.0034	0.0740	0.0709	0.0820	0.0170	0.1110
Zn	0.1240	0.1218	0.1200	0.1181	0.1050	0.0222	0.2400	0.1249	0.1200	0.0100	0.2016
Fe. Colif. ***	74,887	60,636	33,468	51,932	31,278	4,224	187,588	78,045	83,021	23,274	120,000
Fe. Strep	120,910	77,849	67,414	51,547	38,649	5,581	152,359	130,452	134,566	94,545	178,501

* A small event is a rainfall event that produces a stormwater runoff less than the runoff generated from a rainfall of 0.75 inch. Any event which produces a runoff greater than that of 0.75-inch rainfall is a large event.

** VWM is volume-weighted mean. The small event has a weight of 0.265 and the large event has a weight of 0.735 in computing the VWM.

*** The unit of fecal coliform and fecal streptococci is colonies per 100 milliliters. The unit of all other parameters is milligrams per liter.

Table 3.3
Mean Concentration Values For Waller Creek -- Site ID W3A

Site Name:	Waller Creek @ 23rd Street
Drainage Area:	2,643 acres
Land-Use Type:	Mixed
Impervious Cover:	49%

Pollutant Parameters	**All Events** 20 Observations			**Small Events** * 13 Observations				**Large Events** 7 Observations			
	VWM **	Mean	Median	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
TSS	631.9	355.7	211.5	161.9	71.7	12.8	631.4	715.6	756.3	338.2	1135.1
BOD	13.09	13.15	10.83	13.18	9.48	6.35	32.44	13.07	11.61	6.56	20.13
COD	118.2	93.6	75.6	76.4	67.4	30.3	176.2	125.7	125.3	52.4	217.8
TOC	9.88	11.43	10.44	12.74	11.26	8.08	20.56	9.37	8.65	6.39	13.37
NO2+NO3	0.660	0.852	0.757	0.986	0.828	0.480	2.896	0.601	0.567	0.451	0.865
NH3	0.196	0.246	0.155	0.275	0.256	0.058	0.940	0.182	0.145	0.102	0.334
TKN	3.120	2.378	2.550	1.857	1.046	0.559	4.405	3.345	3.110	2.210	5.779
TN	3.780	3.229	3.054	2.843	2.200	1.083	6.981	3.947	3.975	2.661	6.383
TP	0.944	0.706	0.634	0.540	0.437	0.235	1.247	1.016	0.966	0.767	1.387
Cu	0.0273	0.0253	0.0203	0.0098	0.0098	0.0098	0.0098	0.0304	0.0308	0.0070	0.0534
Pb	0.0826	0.0734	0.0805	0.0037	0.0037	0.0037	0.0037	0.0967	0.0969	0.0640	0.1291
Zn	0.1690	0.1393	0.1812	0.0307	0.0307	0.0307	0.0307	0.1936	0.1936	0.1812	0.2060
Fe. Colif. ***	80,210	75,386	54,399	72,828	50,166	18,290	218,261	81,526	82,338	39,368	120,091
Fe. Strep	132,376	96,333	90,743	77,220	72,771	30,314	152,541	142,206	122,181	97,274	200,250

* A small event is a rainfall event that produces a stormwater runoff less than the runoff generated from a rainfall of 0.75 inch. Any event which produces a runoff greater than that of 0.75-inch rainfall is a large event.

** VWM is volume-weighted mean. The small event has a weight of 0.265 and the large event has a weight of 0.735 in computing the VWM.

*** The unit of fecal coliform and fecal streptococci is colonies per 100 milliliters. The unit of all other parameters is milligrams per liter.

Table 3.4
Equations Relating Watershed Mean Concentrations With Development Conditions And Drainage Areas

Pollutant Parameters	Watershed Size	Development Condition	Coeff. a_0	Coeff. a_1	No. of Obs.	R^2	F-test $p > F$
TSS *	------	Low **	5.911	0.3904	6	0.68	0.0420
TSS	------	Medium	34.88	0.3647	12	0.82	0.0000
TSS	------	High	122.9	0.2558	11	0.75	0.0005
BOD	Large	------	-2.844	6.127	12	0.95	0.0000
COD	Large	------	58.31	0.7172	8	0.91	0.0003
COD	Small	------	19.39	1.179	17	0.62	0.0002
$NO_2 + NO_3$	Large	------	0.2162	1.184	12	0.80	0.0001
TKN	Large	------	1.102	1.159	12	0.63	0.0020
TKN	Small	------	0.4763	1.034	17	0.59	0.0003
NH_3	Large	------	0.04917	1.530	12	0.92	0.0000
NH_3	Small	------	0.08299	1.040	15	0.74	0.0000
TN	Large	------	1.336	1.151	12	0.68	0.0010
TN	Small	------	0.7830	0.8814	17	0.51	0.0013
TP	Large	------	0.1012	2.611	12	0.82	0.0001
TP	Small	------	0.08645	1.351	17	0.53	0.0009
Pb	Large	------	9.391	1.986	6	0.87	0.0062
Pb	Small	------	2.885	1.926	15	0.55	0.0015
Zn	Small	------	8.128	2.323	15	0.78	0.0000
Fe. Colif.	Large	------	12,370	2.443	12	0.82	0.0000
Fe. Strep.	Large	------	27,170	1.908	12	0.78	0.0001

* For TSS, $MC = a_0(DA)^{a_1}$; for BOD, $MC = a_0 + a_1(DI)$; for all other parameters, $MC = a_0(DI)^{a_1}$, where MC is mean concentration in milligrams per liter, micrograms per liter (metals), or colonies per 100 milliliters, DA is drainage area in acres, and DI is development index.

** The relationship between gross impervious cover (GIC) and development index (DI) is $GIC = 0.052(DI)^{2.40}$ for $D < 3.4$; $GIC = 1.0$ for $DI \geq 3.4$

The COA tested another O/G separator at the City's Convention Center in the downtown area. This separator is a pre-treatment for a wet pond which was designed to treat storm water runoff from the Convention Center development. The separator has a storage capacity of approximately 4,000 cubic feet, consisting of 4 baffled chambers. This storage receives runoff from a 35-acre downtown commercial area (including the Convention Center) and discharges to an adjacent wet pond through a siphon. The City monitored this separator between January and August 1995 for about 8 rainfall events. The result of this monitoring indicates that this separator has some efficiency in detaining storm water pollutants. This report used a statistical analysis to test the difference between inflow and outflow pollutant concentrations. The Student's t-test for a paired comparison indicates that the separator is effective for some of the pollutant parameters. In addition, it was observed that the oil chamber of the separator always detained substantial scum and floating materials after a rainfall event. The City pumps out these materials periodically.

3.4 Testing of Street Inlet Filters

A street inlet filter is a screen-type trap fitted to the opening of a street drain inlet. The screen of the trap will pass storm water but detain floating materials and large sediment chunks. There is an opening along the rear end of the trap to allow storm water overflows. The COA has monitored the inlet filter to evaluate if the filter provides any water quality benefits. The City tested the storm water discharges from a 3.1-acre downtown commercial area with and without the traps in place. In November 1993 the City placed 8 filter traps in the area and then tested the storm water discharges for 12 rainfall events. The City further tested the discharges for additional 10 events following the removal of the filter traps in October 1994. Based on a statistical plan, this report compared the average event mean concentrations between the two tests. The comparisons show no significant treatment efficiency for any of the pollutant parameters. It was observed, however, that the filter traps caught a large quantity of debris, cans, trash, and sediment chunks following each rainfall event.

4.0 CONTROL MEASURE STUDY

The COA previously experimented various types of storm water control structures (COA, 1990). During the course of this study, the City also evaluated other structural control measures or BMPs under the COA Storm Water Monitoring Program. The following paragraphs describe the characteristics of some control measures under consideration, including their treatment efficiency, design criteria, and maintenance requirements.

4.1 Wet Pond

A wet pond is a detention basin with a permanent storage and extended detention time. With adequate pond design and vegetation arranged in the structure, a wet pond can effectively treat both particulate and dissolved pollutants. The COA retrofitted a flood control detention basin to a wet pond in the early 80's by closing the gate of the outlet work of the detention basin (Woodhollow Detention Pond). The pond has a permanent water storage equivalent to a volume of about half-inch runoff from a 371-acre residential development. The City monitored the pond during 1984-87. Although the retrofit of the pond did not fully comply with the design criteria of a wet pond, i.e., the outflow capacity of the structure is too large to provide sufficient detention time, the monitoring indicated that the structure has good treatment efficiency for some of the pollutant parameters. In late 1994 the COA established 3 storm water monitoring stations to test a well-designed Wet Pond (St. Elmo Street Wet Pond) at the City's Electric Utility Service Center. The Pond has a permanent storage of about 2.50 acre-feet that is equivalent to the volume of 1.10-inch runoff from a 39-acre watershed. Starting in 1995 the City consecutively sampled the inflows and outflows of the pond during rainfall events. The sampling shows that the pond is effective in retaining almost all the storm water runoff pollutants. In addition, the wet pond has the advantage of treating all storm water discharges from the watershed since the entire discharges pass through the pond. Table 4.1 provides a list of treatment efficiency for various BMPs under consideration.

The key design criteria for a wet pond are that the time of residence and volume of permanent storage must be adequate. The required permanent storage can be estimated through a frequency analysis on the size of runoff volume for all storm rainfall events. Generally the permanent storage should not be less than the volume of half-inch runoff from the contributing drainage area of the pond. A draw-down time (time needed to release most of the outflow from the pond) of 24 to 48 hours should provide sufficient detention time. Other design considerations include pond configuration, sediment trap, basin liners, landscape and vegetation, and environmental impacts. The design should provide an environment for the particulate pollutants to settle and the soluble pollutants be consumed by the vegetation. Tables 4.2 specifies the design criteria for some BMPs under consideration.

A wet pond facility requires regular inspection and maintenance. Mowing and clearing within the pond vicinity are usually necessary. Following the completion of the pond, it is necessary to inspect the pond periodically in order to evaluate if the pond operates properly. Subsequently the structure should be inspected every 6 to 12 months to determine if the structure needs any repair or maintenance.

Table 4.1
Treatment Efficiency for Various BMP's (in Percent)

Pollutant Parameter	Dry Pond	Sand Filtration	Wet Pond	Grassed Channel	O/G Separator*
TSS	20-60*	70-90*	50-90*	70**	10**
BOD	20-30	30-50	30-50	30	0
COD	20-30	40-70	30	30	40
NO2+NO3	20-40	(-40)-(-80)	40-60	0	5
TKN	10-40	40-60	10-40	30	20
NH3	20-50	30-80	20-80	40	40
TN	10-20	20-30	30-50	20	-
TP	40-50	50-60	40-80	40	-
DP	10	40	70	30	-
Cu	0-20	60	60	-	-
Pb	20-30	80-90	70	-	-
Zn	-	80	60	-	-
Fecal Coliform	-	20-40	90	-	-
Fecal Strep.	-	20-60	90	-	-
O/G	-	-	-	-	-
TPH	-	-	-	-	-

* Values derived from monitoring of structures of different designs.
** Values derived from monitoring of one structure.

Table 4.2
Design Criteria for Various Water Quality Control Ponds and BMP's

Type of Ponds or BMP's	Filtration Area (Acres)	Avg. Drawdown Time* (Hours)	Vol. of Runoff Treated (Inch Per Acre)	Other Major Consideration
Dry Pond	na	24	≥ 1/2	Baffle & Long Flow Path
Sand Filtration	.003~.005 (A)**	24	≥ 1/2	Pre-treatment & Dimension of Sand Bed
Wet/Dual Purpose Pond	na	36	Vary	Landscape & Vegetation
Grassed Channel	Wide Cross Section Area	Mild Slope	Vary	Vegetation Density
Oil/Grit Separator***	na	4	Vary	Baffle & Long Flow Path

* Drawdown time is the total time required for the outflow to pass through the structure (to pass at least 80% of the outflow). For a wet pond, the residence time of water in the pond should be sufficient. A permanent storage of about 1/2 to 1-inch of runoff from the contributing drainage area generally provides sufficient residence time.

** A is the contributing drainage area above the structure. Filtration area is .003A to .005A depending on type of pre-treatment.

*** An oil/grit separator for storm water treatment should have sufficient storage capacity in order to be effective.

This report evaluated the water quality benefits by modifying the proposed flood control detention basins into wet ponds for a specific watershed retrofit plan (Option 7 plan in the Chan study).

4.2 Sand Filtration Basin

A sand filtration basin is a water quality control pond which has a sand bed to detain storm water pollutants. A filtration bed of fine sand with adequate depth and surface area is effective in detaining pollutants. The COA tested 4 sand filtration basins of different types during 1984-89. The testing indicates that the sand filtration is effective in removing most of the storm water pollutants. Subsequently, the City developed a design guideline (COA, 1989) for sand filtration basin that requires a pre-treatment such as a full or partial sedimentation pond before the storm water enters the sand filtration basin. In July 1993, the City installed four storm water monitoring stations to evaluate the effectiveness of a sedimentation/filtration pond system at Barton Ridge Plaza. The pond system receives and treats the first half-inch of runoff discharged from a 3-acre parking lot for the commercial development. Through a flow separation device, the pond system diverts additional runoff to the downstream flood control detention. The City has monitored the pond system since September 1993. The result of monitoring demonstrates that the pond system is effective in detaining most of the storm water pollutants. Nevertheless, this type of system is generally off-line from the drainage and treats only the first half-inch of runoff. On an annual basis, the system can only treat 70-100 percent of the storm water pollutant loads discharged from the drainage area, depending on the degree of watershed imperviousness. For area with a 90 percent impervious cover, the system can treat about 70 percent of the total annual pollutant load carried by the storm water discharges. This percentage of treatment increases with the decrease of percent impervious area. In addition to this treatment limitation, the sand filtration cannot remove some soluble pollutants such as nitrate and nitrite.

The key design criteria for a sand filtration basin are the dimensions of the sand bed. The sand bed should be composed of fine sand (0.02 ~ 0.05 inch in diameter) with a minimum depth of 12 inches. The surface area of the sand bed should be large enough such that the inflow draw-down time is around 24 hours. A surface area of 0.003 - 0.005 times of the drainage area of the pond is usually adequate. A pre-treatment device such as a full or partial sedimentation chamber will prevent much of the debris and sediment chunks from entering filtration basin.

The difficulty of maintenance for sand filtration basin is to change sand filtration media. For each of the filtration basins monitored, part or all of the sand bed had to be changed after the first year's operation. During the first year of operation, it is necessary to inspect the structure during and after significant rainfall events in order to find the problems of the structure, such as drain clogging, overflow from sand filtration pond, and leaks of water from the system. After the first year, it is necessary to inspect the structure every 6 to 12 months in order to properly maintain the structure.

In accordance with the COA Urban Watershed Ordinance, most of the new development and re-development requires the implementation of sand filtration systems in the Waller Creek basin, in order to mitigate storm water pollution.

4.3 Dry pond or Sedimentation Pond

A dry pond is a detention basin with extended detention time. With adequate detention time, a dry pond has some effectiveness in detaining storm water pollutants. The COA has tested dry ponds in 1984-87 and 1993-96. The key problems of a dry pond are scouring of the pond bottom and the re-suspension of sediments. On an annual basis, a dry pond with adequate detention time provides fairly good treatment efficiency. A pond draw-down time of 24-48 hours is adequate. Based on the monitored data, a draw-down time of more than 48 hours will not materially improve the treatment efficiency.

The main consideration in designing a dry pond is detention time and a screening device to prevent pond drain from clogging. Baffles and a sediment trap are generally needed. Baffles can slow down flow velocity and prolong detention time.

The maintenance of a dry pond can be cumbersome. The most common problem of a dry pond is the clogging of the drainage. Frequent inspections at the beginning of the operation are necessary to observe and correct if clogging occurs. Subsequent inspection every 6 to 12 months is needed for proper maintenance. Excessive sediments should be removed from the structure.

This report evaluated the water quality benefits by modifying the proposed flood control detention basins into dry ponds for a specific watershed retrofit plan (Option 7 plan in the Chan study).

4.4 Vegetated Channels

Starting in September 1993, the COA established storm water monitoring stations at the drainages of two single-family residential areas in the same subdivision. These two subdivisions have similar development conditions, i.e., equivalent drainage areas of about 41 acres and impervious cover of 33-39 percent. The drainage of one area is routed through a storm sewer pipe system, while the other is routed through an earth channel. The channel has a flat, wide trapezoidal cross section and is covered with grass and other types of vegetation. The slope of the channel is generally mild.

The runoff flows at both stations were continuously monitored under the same storm rainfall conditions during 1993-1995. The paired data collected from the monitoring indicates that the storm water discharges from the vegetated channel had significantly smaller flow rates and mean pollutant concentrations as compared to those from the sewer-pipe system. In other words the vegetated channel can effectively detain some of the pollutants.

This report promotes the creation of vegetated conveyance system in association with any proposed watershed retrofit plans.

5.0 WATERSHED DATA FOR SWMM MODEL

This grant study adopted the EPA's Storm Water Management Model (SWMM) for watershed simulations. The study used the following data for the development, calibration, and verification of the model for the Waller Creek basin.

5.1 Flow Data

The study used storm water streamflow data collected at Waller Creek @ 23rd Street and Waller Creek @ 38th Street for SWMM calibration. Flow depth measurements from the two in-stream gauging stations were converted to flow rates using tables developed by the USGS (as described in Section 3.1).

5.2 Rainfall Data

Rainfall data collected by the COA Drainage Utility's Flood Early Warning System (FEWS) and Storm Water Monitoring Program (SWMP) were processed for use in calibration of the model and in watershed simulations using SWMM.

5.2.1 Rain Gauges

Nine rain gauges provided rainfall data for the SWMM model. This included eight FEWS rain gauges plus the SWMP rain gauge located on Waller Creek at the 23rd Street monitoring site. All rain gauges were the tipping bucket type. The FEWS gauges report instantaneously after accumulating 1 millimeter (approximately 0.04 inch) of rainfall. The SWMP gauge reports every one minute and accumulates 0.01 inch of rainfall per tip. The locations of the rain gauges are specified in Table 5.1 and Figure 7.

Table 5.1
Location of Rain Gauges

FEWS	Address	Longitude	Latitude	USGS Topo.	City Grid
2230	7500 Bennett Ave.	97-41-50W	30-20-08N	170 Austin East	L 28
2400	2500 W 45th St.	97-44-53W	30-19-05N	169 Austin East	J 26
2410	6500 Arroyo Seca	97-43-56W	30-20-13N	169 Austin East	J 28
3000	500 E. 12th St.	97-44-06W	30-16-20N	189 Austin East	J 22
3100	4400 Ave. F	97-43-38W	30-18-28N	189 Austin East	K 25
3110	3800 Guadalupe St.	97-44-17W	30-18-11N	189 Austin East	J 25
3120	500 W. Koenig Ln.	97-43-21W	30-19-22N	169 Austin East	K 27
3130	3200 Hemphill Park	97-44-18W	30-17-53N	189 Austin East	J 25
SWMP	Address	Longitude	Latitude	USGS Topo.	City Grid
3123	Waller Ck. at 23rd St.	97-44-02W	30-17-09N	189 Austin East	J 24

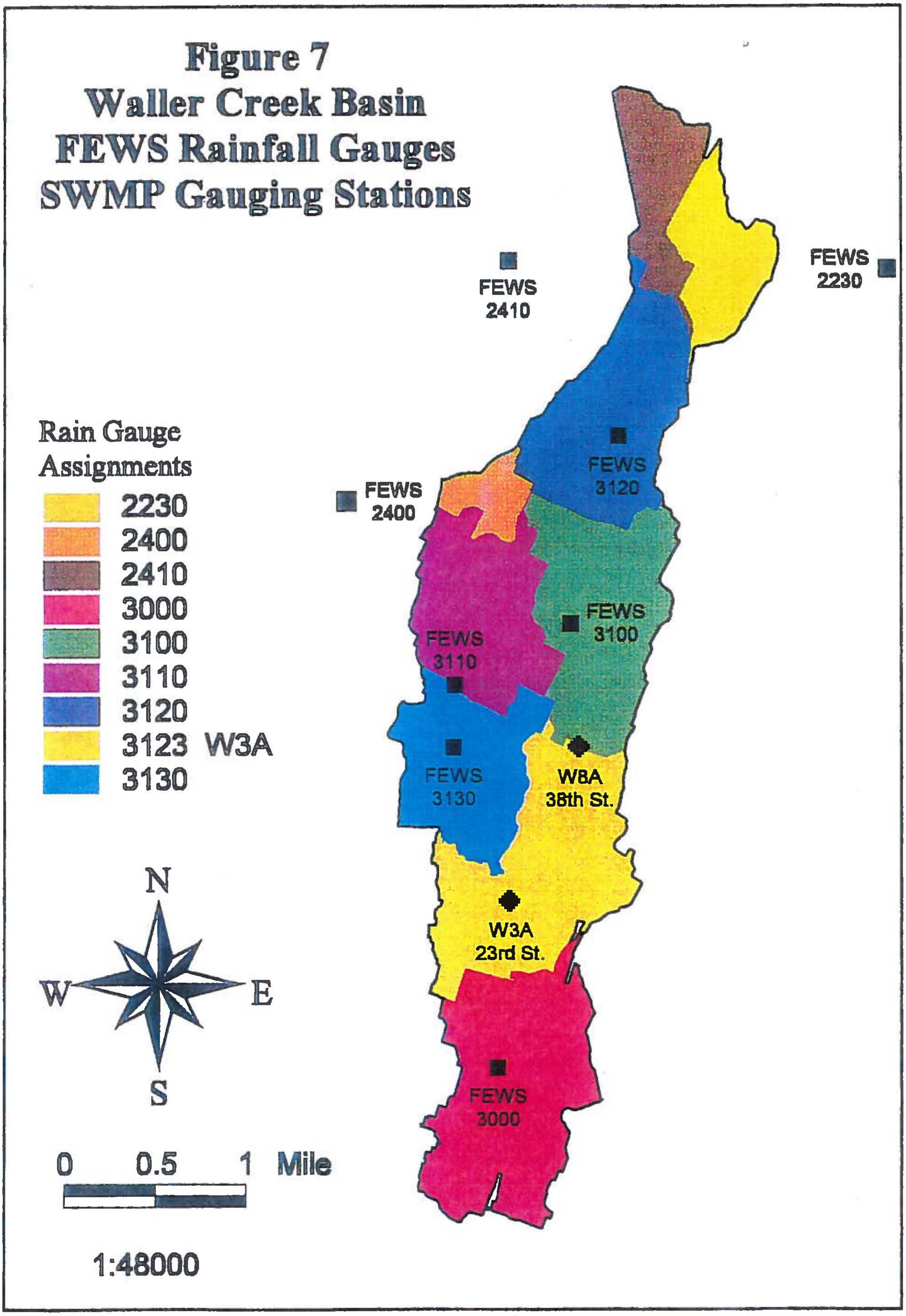


Figure 7
Waller Creek Basin
FEWS Rainfall Gauges
SWMP Gauging Stations
Rain Gauge
Assignments
2230
2400
2410
3000
3100
3110
3120
3123 W3A
3130
FEWS
2410
FEWS
2230
FEWS
3120
FEWS
2400
FEWS
3100
FEWS
3110
FEWS
3130
W8A
38th St.
W3A
23rd St.
FEWS
3000
N
W
E
S
0 0.5 1 Mile
1:48000

5.2.2 Validation of the Rainfall Record

The COA collects FEWS rainfall data to provide information for flood warning. Data validation is not required for that purpose. The following process was used to validate the raw data:

- The raw FEWS data are reported as cumulative volume. Occasional errors in transmission of the data cause scrambling of the data bits. These are usually identified as values that are out of sequence. These out of sequence values were corrected, if logically correctable, or deleted.
- A C-language computer program was developed to convert FEWS rainfall data to a fixed interval format. Rainfall was considered to be uniformly distributed between the current report and the previous report, if the previous report occurred in the same rainfall event. For each rainfall event containing more than one record, the first interval of rainfall was considered to be distributed identically to the second interval of rainfall. For events containing only one record, rainfall was distributed at an intensity of 0.01 inch per minute.
- The rainfall record of all nine stations was converted to a two minute interval format. A SAS (SAS Institute, 1994) computer program was use to merge all the data by date and time into one database. The data for each rainfall event was visually inspected to ensure that the data appeared to be naturally distributed. Apparent data errors were corrected by substituting rainfall data from the next closest gauge. The most common data errors were:

  - Station was not reporting or out of service.
  - Station became clogged, followed by prolonged leaking at a slow rate.
  - Station became clogged, followed by dumping at a very fast rate.

5.3 Watershed Data from GIS Applications

This study used Geological Information System (GIS) extensively for the SWMM development. First of all, the Waller Creek basin was formulated as a subwatershed and channel system for the adoption of SWMM. Each subwatershed is characterized by its watershed data such as drainage area, channel length, basin slope, and the degrees of impervious cover and tree cover. Table 5.2 presents a summary of watershed data for the 23 Waller Creek subwatersheds.

Table 5.2
Watershed Data for 23 Waller Creek Subwatersheds

SWMM ID	Rain Gauge	Drainage Area	Channel Length	Watershed Slope	Impervious Cover	SFR Imp. Cover	Tree Cover
-		Acres	Feet	%	%	%	%
1	2410	218.7	7560	1.59	49.2	13.5	12.5
3	·2230	231.7	4114	2.04	48.1	25.4	17.7
5	3120	130.4	1982	2.25	53.0	16.2	17.4
7	3120	115.5	1598	2.67	60.6	10.5	15.4
9	3120	236.5	2710	2.90	51.4	21.1	21.0
11	3100	73.1	1759	3.10	31.7	11.9	12.0
13	3100	122.0	2662	2.29	45.4	24.3	36.4
15	3100	127.0	4347	2.99	43.2	33.2	41.4
17	3100	32.6	3136	3.21	40.2	32.0	44.5
19	3100	155.1	3748	4.44	31.7	21.6	28.5
21	3123	225.4	4909	4.58	39.4	23.7	40.1
23	2400	92.6	2497	1.30	51.0	3.3	8.1
25	3110	155.8	6095	1.66	50.5	4.9	9.1
27	3110	263.9	5697	1.51	52.4	12.9	14.8
29	3130	68.8	1573	2.96	56.2	22.2	28.1
31	3130	116.9	1540	3.43	55.9	17.6	32.8
33	3130	196.7	3394	3.59	55.9	15.0	24.7
35	3123	60.9	823	5.03	69.3	0.0	13.0
37	3123	322.7	2741	4.51	71.5	0.9	12.1
39	3000	70.0	1925	5.02	73.8	0.0	9.8
41	3000	159.3	1237	4.58	66.7	2.1	11.7
43	3000	236.5	2979	4.93	69.9	7.8	18.0
45	3000	178.6	2503	2.03	67.8	7.4	14.6

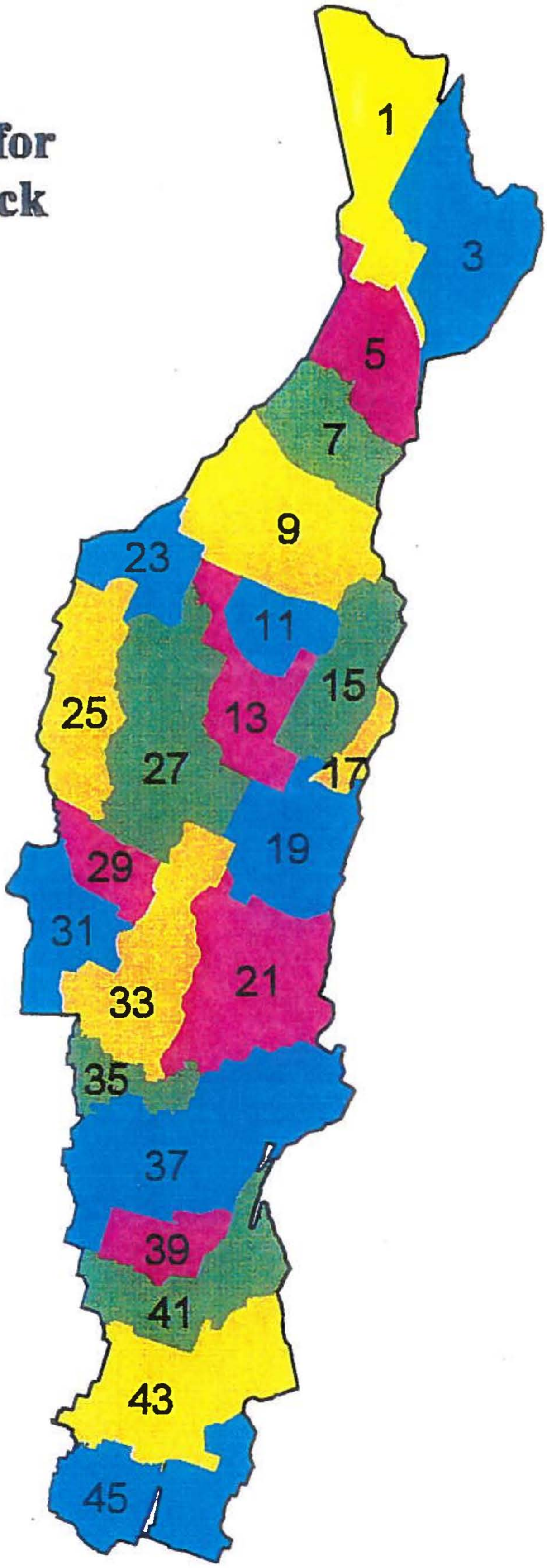
5.3.1 Subwatershed Delineation

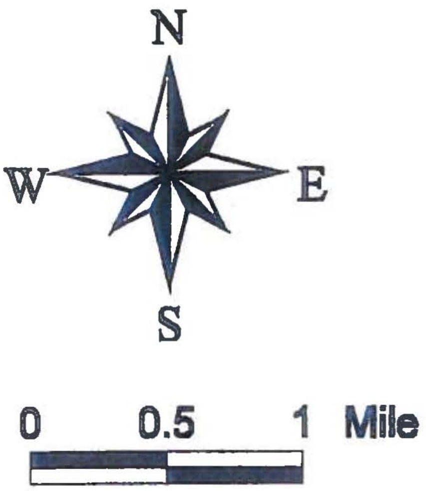
This study used COA topographic maps (scale: 1 inch = 200 feet) to trace subwatershed boundaries. Elevations in the topographic maps were represented by 2-foot interval contours. Field inspection of the boundaries was performed where elevation contours were ambiguous or diversion of runoff flow through storm sewers was suspected. Channel locations and subwatershed boundaries from the topographic maps were digitized using ARC/INFO software (ESRI, 1994). Channel lengths and subwatershed areas were directly computed from the resulting subwatershed boundary coverage. Figure 8 shows subwatersheds and their ID's for the Waller Creek basin.

Figure 8
Waller Creek Basin Subwatershed System for SWMM RUNOFF Block

Outlets

1. RR tracks near Airport Blvd.
3. RR tracks near Airport Blvd.
5. Reilly School Detention Pond
7. W. Koenig Lane
9. 51st Street
11. U. T. Intramural Field Detention Pond
13. Duval Street from West
15. Duval Street from East
17. S. E. of Southern End of Barrow St.
19. W8A Gauging Station (near 38th St.)
21. Confluence of Main and Hemphill Br.
23. Texas School for the Blind Det. Pond
25. Central Park Detention Pond
27. 38th Street and Gualdalupe
29. 33rd Street above Hemphill Park
31. 30th Street below Hemphill Park
33. Confluence of Main and Hemphill Br.
35. W3A Gauging Station (near 23rd St.)
37. Martin Luther King Blvd.
39. 15th Street
41. 12th Street
43. 5th Street
45. Town Lake (East of Davis Street)





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The following is a list of the drainage outlets for each subwatershed:

SWMM ID	Outlet from Subwatershed
1	RR tracks near Airport Blvd. (from the West)
3	RR tracks near Airport Blvd. (from the North)
5	Reilly School Detention Pond
7	West Koenig Lane
9	51st Street
11	University of Texas Intramural Field Detention Pond
13	Duval Street from West
15	Duval Street from East
17	South East of Southern End of Barrow Street
19	W8A Gauging Station (near 38th Street)
21	Confluence of Main Channel and Hemphill Branch (from Main Channel)
23	Texas School for the Blind Detention Pond
25	Central Park Detention Pond
27	38th Street and Guadalupe
29	33rd Street above Hemphill Park
31	30th Street below Hemphill Park
33	Confluence of Main Channel and Hemphill Branch (from Hemphill Br.)
35	W3A Gauging Station (near 23rd Street)
37	Martin Luther King Blvd.
39	15th Street
41	12th Street
43	5th Street
45	Town Lake (East of Davis Street)

5.3.2 Watershed Slope

Watershed slope was computed from a contour coverage, digitized from the USGS topographic maps. The coverage had 10-foot contour intervals. Within each subwatershed, transects were drawn perpendicular to the contour lines, in the direction of flow. The transects were approximately equidistant. The slope of the transect was equal to the difference in elevation of the end points divided by the length of the transect, which was computed directly by the GIS software. For each subwatershed, the average slope was computed as the length weighted mean of the slopes of each transect within the subwatershed. Since the transects were approximately equidistant, the length weighted mean was approximately equal to the area weighted mean. Figure 9 provides the watershed contour map for the Waller Creek basin.

5.3.3 Soils and Land-Use

Soil and land-use coverages (COA, 1995) were overlaid by the subwatershed coverage in order to compute soil type percentages and land-use percentages for each subwatershed. Figures 2 and 4 present land-use and soil distributions for the Waller Creek basin.

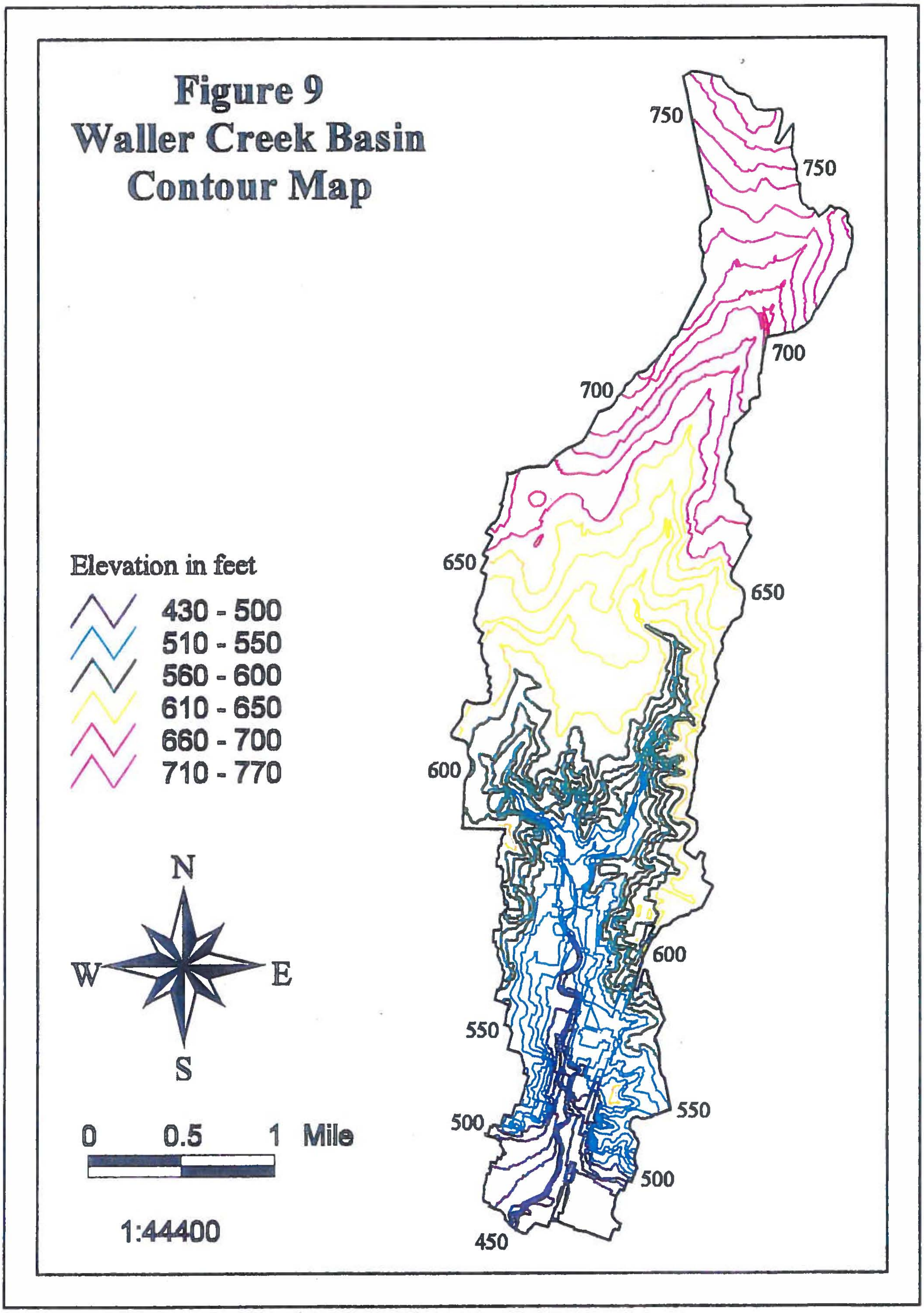


Figure 9
Waller Creek Basin
Contour Map
Elevation in feet
430 - 500
510 - 550
560 - 600
610 - 650
660 - 700
710 - 770
N
W
E
S
0
0.5
1
Mile
1:44400
750
750
700
700
650
650
600
600
550
550
500
500
450

5.3.4 Gross Impervious Cover

Unfortunately, a digitized coverage of gross impervious cover for the Waller Creek basin was not available. Therefore, it was necessary to construct a gross impervious cover coverage from the land-use coverage. First, large areas of land-use were subdivided into smaller polygons of nearly homogenous land-use types that can represent specific gross impervious percentages. This method worked quite well for single-family residential land-use, which could be subdivided into polygons based on construction subdivisions. Next, each land-use polygon was assigned a gross impervious cover percentage using the COA estimates for its Town Lake Study (COA, 1992). Examples are:

Single Family Residential	38%
Multi-Family Residential	65%
Industrial	72%
Office	85%
Commercial	85%

For some of the smallest land-use polygons, these values would not be changed. However, more than ninety percent of the total watershed area was evaluated by other methods to give improved estimates of gross impervious cover percentages. Three different methods, each using COA planimetric maps (scale: 1 inch = 200 feet), were used to achieved these improved estimates.

For the first and most precise method, additional polygons were digitized directly from the planimetric maps, to create polygons that were either nearly all pervious cover or nearly all impervious cover. Many large areas including the main campus of the University of Texas, the Department of Public Safety, the State Hospital, and the Hunstman (formerly Texaco) chemical plant were evaluated by this method.

For the second method, a representative sub-region was evaluated for impervious cover percentage and the estimate was applied to the entire region. For example, the gross impervious cover percentage of a single family residential subdivision could be estimated from the percentage of a representative block. For this method, the percentage was estimated by hand calculations from the planimetric map.

For the last and least precise method, gross impervious cover percentage was estimated simply by visual inspection of the planimetric map. This method was used primarily for the evaluation of small land-use polygons.

Figure 3 shows the impervious cover distribution map for the Waller Creek basin.

5.3.5 Tree Cover

The gross impervious cover coverage described in the previous section had polygons whose attributes were land-use types and percentages of gross impervious cover. Percentage of tree cover was added as a third attribute to the gross impervious cover coverage. Tree cover percentages were estimated by visual inspection from the planimetric map. Regions that spanned several City blocks were estimated as the mean of the estimates for each City block within the region. Estimates of tree cover were completed as an additional check and were not intended to be as precise as estimates of gross impervious cover. Figure 10 provides a tree cover percentage distribution map for the Waller Creek basin.

5.4 Development of Soil Parameters

Soils information generated from the GIS data consists of percentage of pervious watershed area for different soil types. These results are summarized in Table 5.3. The following is a list of U. S. Soil Conservation Service (SCS) soil series and hydrologic groups found in the Waller Creek basin:

Hydrologic Group	Code	Soil Series
C	AlD	Altoga
B	Bh	Bergstrom
B	Fs	Frio
D	HsD	Houston Black
C	LeB	Lewisville
C	TuD	Travis
C	UsC	Urban
C	UtD	Urban
-	Ur	Urban

5.4.1 Soil Texture Class

Soil texture classes were clay, clay loam, loam, and silt loam. Usually, each soil type consists of different depths of individual soil texture layers. For each soil type, the overall percentage of soil texture class was computed as the depth weighted percentage of the soil texture class of each layer. Subsequently, the area weighted percentages of the soil texture classes for each subwatershed were computed. The results are summarized in Table 5.4.

5.4.2 Hydraulic Conductivity of Soil

For each soil type, the hydraulic conductivity range of soil of various layers was considered to be the conductivity range of the specific layer which has the lowest conductivity range among all layers. Subsequently, the area weighted percentages of hydraulic conductivity ranges for each subwatershed were computed. Ranges of hydraulic conductivity were 0.02 to 0.063, 0.063 to 0.20, 0.20 to 0.63, and 0.63 to 2.0 inch per hour. Table 5.4 provides a distribution of soil texture class and conductivity values for each identified watershed.

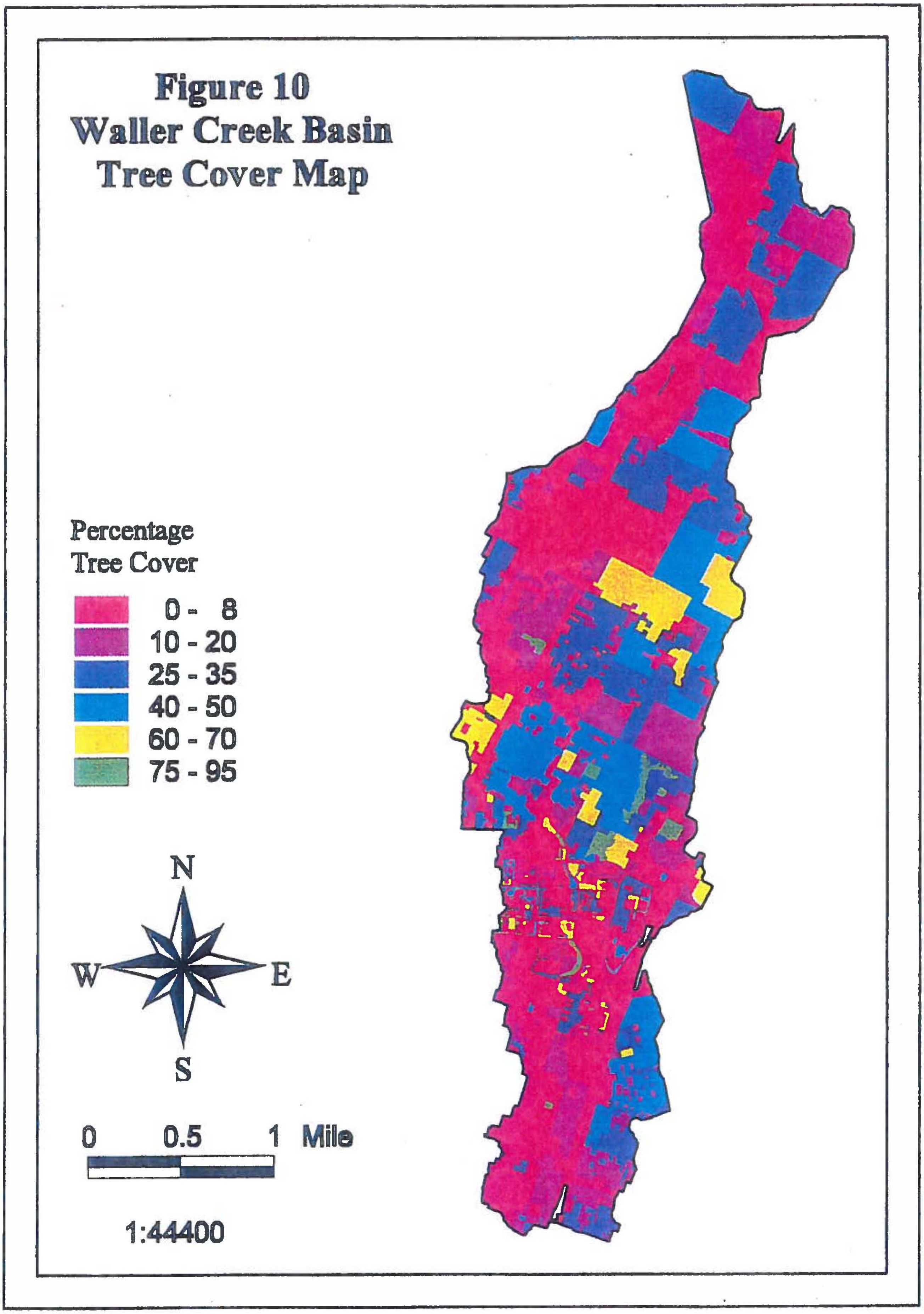


Figure 10
Waller Creek Basin
Tree Cover Map
Percentage
Tree Cover
0 - 8
10 - 20
25 - 35
40 - 50
60 - 70
75 - 95
N
W
E
S
0
0.5
1 Mile
1:44400

Table 5.3
Types of Soil in Each Subwatershed
Presented as Percentage of Pervious Area

ID	AlD	Bh	Fs	HsD	LeB	TuD	Ur	UsC	UtD
1	0.00	0.00	0.00	4.98	0.00	0.00	0.00	70.27	24.75
3	0.00	0.00	0.00	17.09	0.00	0.00	0.00	34.96	47.95
5	0.00	0.00	0.00	40.91	0.00	0.00	0.00	38.07	21.02
7	0.00	0.00	0.00	43.99	2.85	0.00	0.00	14.55	38.62
9	0.00	0.00	0.00	24.18	4.39	0.00	0.00	45.15	26.28
11	0.00	0.00	0.00	26.16	5.36	0.00	0.00	37.52	30.95
13	0.00	0.00	0.00	18.80	18.14	6.33	0.00	46.19	10.54
15	35.20	0.00	0.00	0.79	62.66	0.00	0.00	0.00	1.36
17	2.54	0.00	0.03	0.78	55.48	0.00	0.00	0.00	41.16
19	0.00	0.00	8.06	2.98	0.00	25.09	0.00	34.68	29.18
21	0.00	0.00	1.98	0.00	0.00	7.02	61.32	7.75	21.92
23	0.00	0.00	0.00	17.29	0.00	0.00	0.00	63.21	19.50
25	0.00	0.00	0.00	0.20	0.00	26.21	0.00	70.90	2.70
27	0.00	0.00	0.00	9.35	0.00	33.77	0.00	56.05	0.84
29	0.00	0.00	0.00	0.06	21.90	45.11	0.00	4.90	28.03
31	0.00	0.00	0.00	3.10	0.00	1.27	53.24	24.54	17.86
33	0.00	0.00	0.00	0.00	2.20	12.66	56.78	12.82	15.54
35	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	95.69	0.00	4.31
39	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	6.11	77.47	0.00	16.42
43	0.00	0.00	0.00	0.00	0.00	27.81	60.96	0.00	11.23
45	0.00	13.80	0.00	0.00	0.00	9.80	76.38	0.00	0.02

Table 5.4
Soil Texture Class and Hydraulic Conductivity
for Each Subwatershed Presented as Percentage of Pervious Area

WS	Soil Texture Class				Hydraulic Conductivity Range			
ID	Clay	Clay Loam	Loam	Sandy Loam	0.02 to 0.06 in/hr	0.06 to 0.20 in/hr	0.20 to 0.63 in/hr	0.63 to 2.00 in/hr
	%	%	%	%	%	%	%	%
1	71.2	28.6	0.2	0.0	1.8	0.0	98.2	0.0
3	75.3	24.7	0.0	0.0	15.3	0.0	84.7	0.0
5	86.0	14.0	0.0	0.0	52.0	0.0	48.0	0.0
7	84.6	13.8	1.6	0.0	50.0	0.0	47.3	2.7
9	77.6	19.2	3.2	0.0	28.9	0.0	65.7	5.4
11	77.1	20.1	2.8	0.0	26.4	0.0	68.9	4.7
13	68.0	18.3	12.4	1.3	17.4	7.1	54.8	20.7
15	30.0	31.4	38.6	0.0	0.4	0.0	1.0	98.6
17	52.0	12.9	35.2	0.0	1.2	0.0	38.0	60.8
19	57.9	36.9	0.0	5.2	2.7	28.0	69.2	0.0
21	66.6	31.6	0.0	1.7	0.0	9.3	90.7	0.0
23	78.8	21.2	0.0	0.0	27.2	0.0	72.8	0.0
25	64.4	30.3	0.0	5.4	0.2	28.7	71.1	0.0
27	67.2	27.4	0.0	5.4	10.2	29.0	60.8	0.0
29	53.9	22.9	16.0	7.1	0.1	38.2	34.9	26.8
31	71.9	27.7	0.0	0.3	5.1	1.8	93.1	0.0
33	67.7	29.0	1.2	2.1	0.0	11.1	86.9	2.0
35	70.8	29.2	0.0	0.0	0.0	0.0	100.0	0.0
37	70.8	29.2	0.0	0.0	0.0	0.0	100.0	0.0
39	70.8	29.2	0.0	0.0	0.0	0.0	100.0	0.0
41	67.7	29.7	0.0	2.6	0.0	13.7	86.3	0.0
43	57.2	31.7	0.0	11.1	0.0	59.7	40.3	0.0
45	49.1	33.0	14.3	3.6	0.0	19.4	56.1	24.5

5.5 Natural Channel Data

Table 5.5 contains data for natural channels used in the SWMM TRANSPORT block. Channel length and channel slope were computed from the watershed coverage. Manning's Roughness Coefficient is a length weighted average from the HEC-2 model (Chan & Associates, 1995). Later in Section 6.4.2 there is a discussion of the estimation of channel depth and channel top width for the natural channels.

Table 5.5
Natural Channel Data

Channel ID	Up-Stream Element	Down-Stream Element	Channel Length Ft.	Channel Slope Ft.	Coeff. of Rough-ness	Channel Depth Ft.	Channel Top Width Ft. Sq.	Up-Stream Area
4601	45	46	1251.6	0.614	0.0494	14.83	86.6	3501.5
4501	44	45	1251.6	0.601	0.0495	14.62	85.6	3412.2
4401	43	44	1489.6	0.785	0.0422	14.34	84.2	3294.0
4301	42	43	1489.6	0.838	0.0395	14.06	82.8	3175.7
4201	41	42	618.6	0.419	0.0507	13.86	81.9	3096.1
4101	40	41	618.6	0.672	0.0513	13.66	80.9	3016.4
4001	39	40	962.5	0.628	0.0450	13.58	80.5	2981.4
3901	38	39	962.5	0.466	0.0411	13.49	80.1	2946.4
3801	37	38	1370.7	0.833	0.0459	13.08	78.1	2785.0
3701	36	37	1370.7	1.051	0.0471	12.65	76.0	2623.7
3601	35	36	411.4	0.743	0.0497	12.57	75.6	2593.2
3501	22	35	411.4	1.162	0.0496	12.49	75.2	2562.8
2201	21	22	2454.3	0.549	0.0468	9.49	60.1	1555.3
2101	20	21	2454.3	0.978	0.0501	9.11	58.1	1442.6
2001	19	20	1613.6	1.008	0.0524	8.83	56.7	1365.1
1901	18	19	1613.6	0.640	0.0414	8.55	55.2	1287.5
1801	14	18	526.0	1.252	0.0395	8.43	54.5	1254.8
1401	13	14	1331.2	1.052	0.0415	7.71	50.7	1066.8
1301	12	13	1331.2	0.558	0.0461	7.47	49.4	1005.8
1201	11	12	879.3	0.889	0.0540	7.32	48.6	969.3
1101	10	11	879.3	0.598	0.0511	7.17	47.7	932.7
1001	9	10	1355.2	0.739	0.0398	6.65	44.9	814.8
901	8	9	1355.2	0.720	0.0387	6.10	41.8	696.3
801	7	8	799.1	0.733	0.0375	5.82	40.2	638.5
701	6	7	799.1	0.793	0.0376	5.52	38.6	580.8
601	5	6	991.2	0.673	0.0354	5.17	36.6	515.6
501	4	5	991.2	1.068	0.0394	4.80	34.4	450.4
3401	33	34	1758.9	0.774	0.0500	6.57	44.5	796.4
3303	3302	33	312.1	1.245	0.0500	6.49	44.0	778.9
3302	3301	3303	838.9	0.477	0.0500	6.27	42.8	732.0
3301	32	3302	607.9	1.974	0.0500	6.11	41.9	698.0

Numbers less than 100 are inlets.
Numbers greater than 100 are channel elements.
Even inlets mark the outlet of the subwatershed.
Odd inlets mark the center of the subwatershed.
Odd inlets have the same ID as the subwatershed in the RUNOFF block.

6.0 STORM WATER MANAGEMENT MODEL (SWMM) FOR THE WALLER CREEK BASIN

This section discusses model development, calibration coefficients for SWMM input parameters, model calibration and verification by minimization of an error function, and continuous simulations of the SWMM model for the Waller Creek basin.

6.1 Model Development

In developing a SWMM model for the Waller Creek basin, the basin was divided into 23 subwatersheds ranging in area from 32.6 to 322.7 acres, as shown in Table 5.2. Of these 23 subwatersheds, 6 were terminal in the sense that their main channel did not receive inflow from upstream elements. The runoff from these 6 subwatersheds (1, 3, 15, 17, 23, 25) was routed in the SWMM RUNOFF block, with one channel element per subwatershed. The runoff from these subwatersheds, introduced at the upstream end of the channel, was uniformly distributed along the entire length of the channel. This approximates the situation in which channels receive distributed inflows along their lengths.

Of the 23 subwatersheds, 17 were non-terminal in the sense that their main channel received inflow from upstream elements. The runoff from these 17 subwatersheds (5, 7, 9, 11, 13, 19, 21, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45) was routed in the SWMM TRANSPORT block, with two channel elements per subwatershed. Each channel element routed in the TRANSPORT block represented exactly one half of the total length of the channel in its respective subwatershed. Conceptually one channel element carries upstream inflow. The other element carries the total outflow, i.e., the sum of upstream inflow and runoff generated from the subwatershed. Separate computations of channel slope and Manning's roughness coefficient were made for each element. The runoff generated from each non-terminal subwatershed was introduced in a lump sum at the center of the subwatershed. In addition, one channel segment was added to represent the reach between subwatersheds 15 and 17. One channel in the Hemphill Branch basin (subwatershed 33) was modeled as four elements, because of severe differences in channel slope. Two other channels in the Hemphill Branch basin were subdivided to represent different channel geometries (sewer pipe diameters).

Thus the SWMM model consists of 23 subwatersheds and 6 channel elements modeled in the RUNOFF block and 40 channel elements modeled in the TRANSPORT block. In addition, two to five flood control detention basins were modeled as storage units in the TRANSPORT block. For the existing condition there are two detention basins, one wet pond at 38th Street and one depression storage near the School of Blind. The proposed improvement plan has 5 ponds, consisting of one existing wet pond, three new basins, and the remodeling of the existing depression storage. Figure 11 presents a map of conveyance system and the locations of detention basins for Waller Creek. Figure 12 presents the details of the channel routing system of the Waller Creek basin for SWMM.

Figure 11
Waller Creek Basin
Detention Ponds
and Conveyances

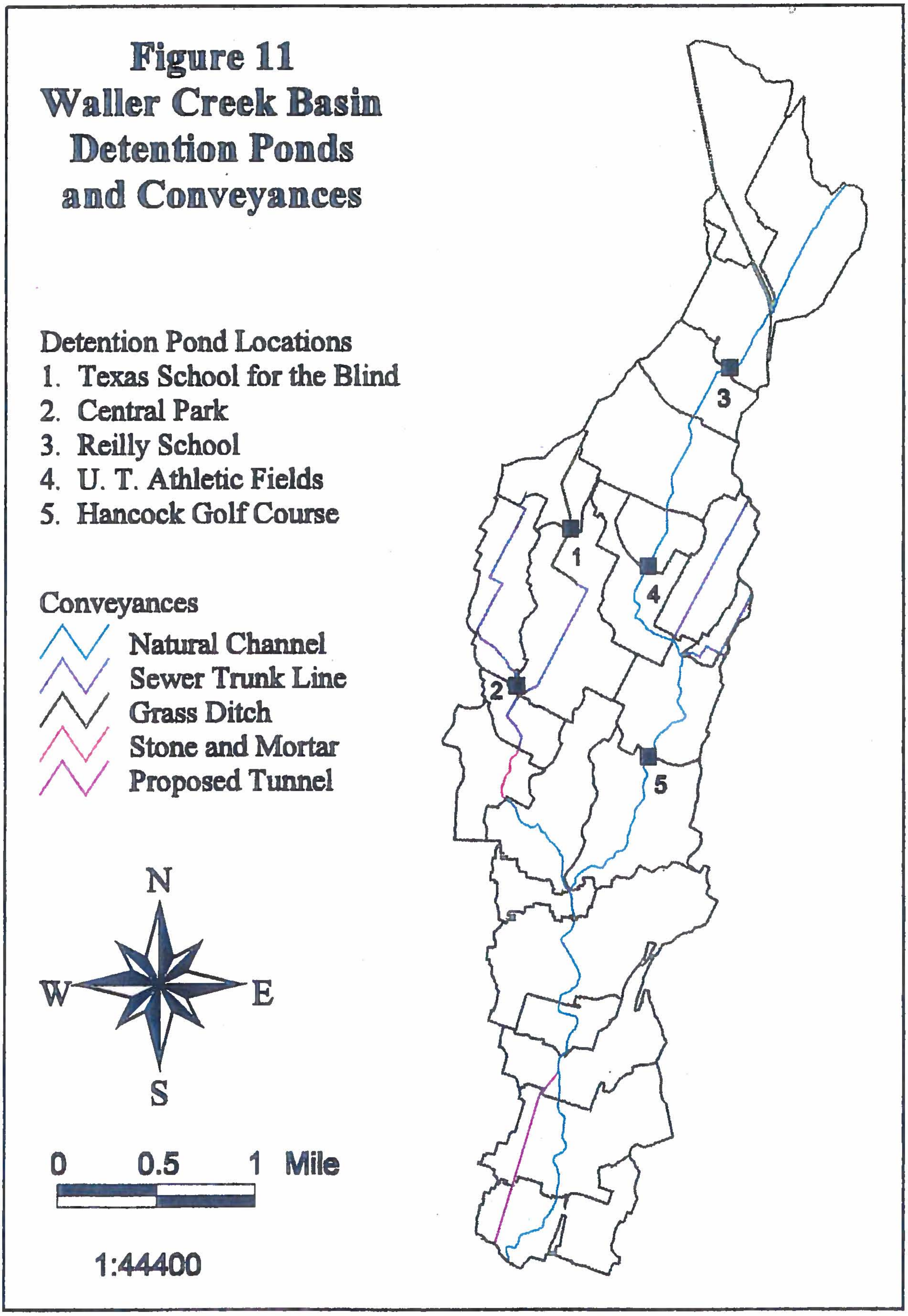
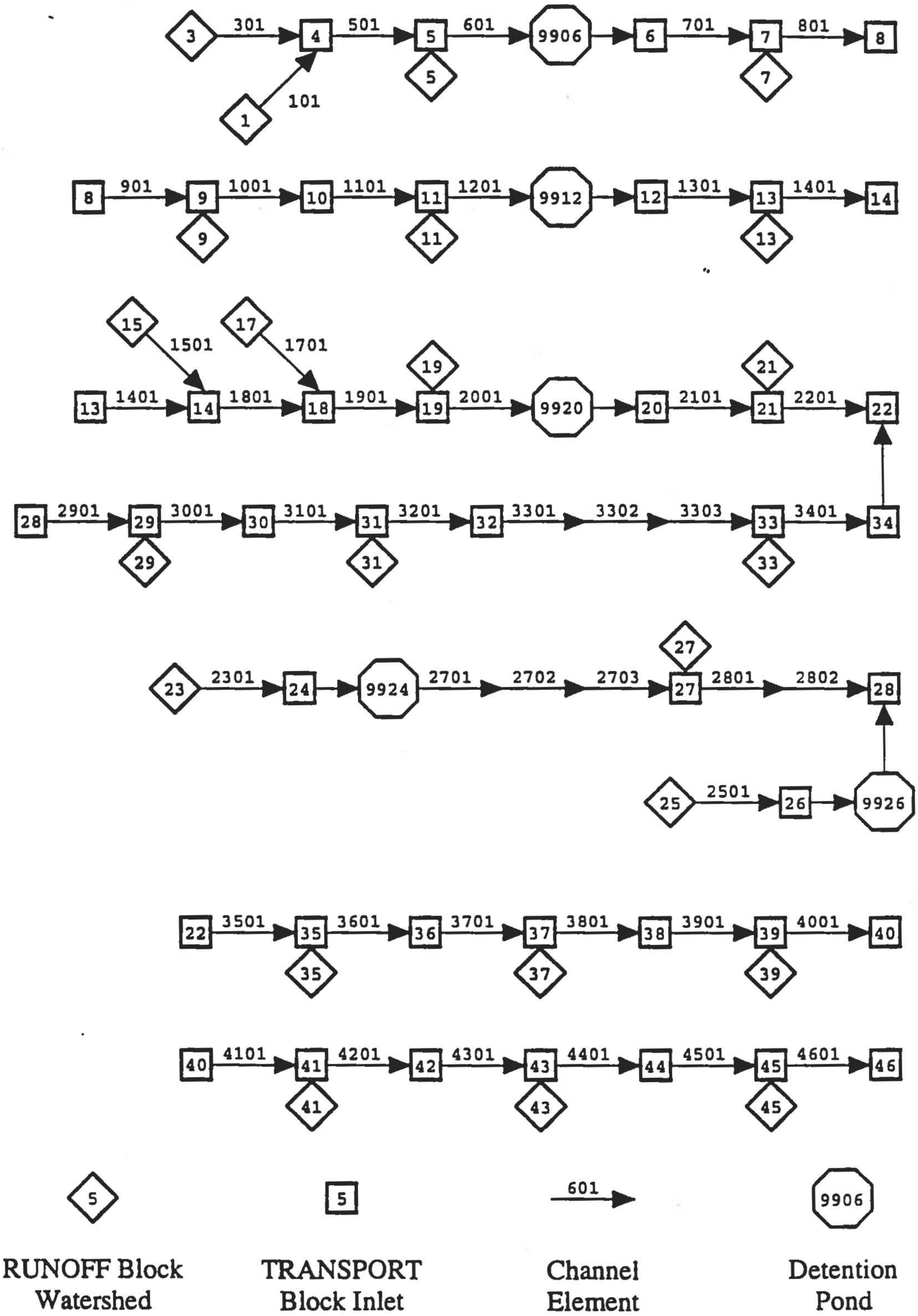


Figure 12
Waller Creek Basin
Channel Routing System for SWMM



6.2 Calibration Coefficients for SWMM Input Parameters

In order to calibrate the watershed model, calibration coefficients were applied to many of the SWMM input parameters. The following is a list of coefficients for each parameter:

Coefficients	Calibrated SWMM Input Parameters
1	Pan evaporation rate
2	Effective impervious cover
1	Watershed impervious roughness
2	Watershed pervious roughness
2	Impervious detention
1	Percent impervious cover with detention storage equal to zero
1	Saturated hydraulic conductivity
1	Initial moisture deficit
1	Capillary suction
1	Channel power function exponent
1	Natural channel roughness
1	Concrete channel roughness

6.3 SWMM Input Parameters for the RUNOFF Block

The calibration coefficients either quantify or modify the SWMM input parameters. As shown above, each parameter has 1-2 calibration coefficients. The following subsections show how the input parameters are quantitatively related to the calibration coefficients.

6.3.1 Evaporation Rate

Parameters and coefficient are:

ER, Evaporation rate (SWMM input parameter),
PER, NWS (National Weather Service) pan evaporation rate, and
A0, Calibration coefficient.

Equation --

$$ER = A0 * PER \qquad \text{Equation 6.1}$$

Evaporation rate was computed by Equation 6.1. The initial value of the calibration coefficient was 0.700. The final value of the calibration coefficient was 0.805.

6.3.2 Effective Impervious Cover

Parameters and coefficients are:

GIC, Gross Impervious Cover,
E IC, Effective Impervious Cover,
CIC, Connected Impervious Cover,
SFRIC, Impervious Cover for single family residential area, and
A0, A1, Calibration Coefficients.

Equations are:

$EIC = A0 * GIC$ Equation 6.2

$EIC = A0 * (GIC - SFRIC) + A1 * SFRIC$ Equation 6.3

This study considers gross impervious cover to be the total percentage of all types of impervious cover. Also, effective impervious cover means the best value of impervious cover for use in the SWMM model. Connected impervious cover means impervious cover that is directly connected to sewers.

For large storms, EIC approaches GIC in magnitude. For small storms, EIC approaches CIC in magnitude. The value needed for SWMM modeling, effective impervious cover, is unknown. By using Equation 6.2, the value of effective impervious cover is estimated from the value of gross impervious cover computed from GIS data. Initial calibration runs established A0 to be approximately equal to 0.6. For many land-uses, such as commercial and office, it was believed that the value of A0 should be much higher, perhaps greater than 0.8. Therefore, it seemed appropriate to make effective impervious cover a function of land-use.

In the Waller Creek basin, one large area of a land-use, the campus of the University of Texas, had nearly all roof tops directly connected by rain gutters to the sewer system. As a contrast, another large area of the basin, that represented by single family residential land-use, had a very low connectivity. Many neighborhoods of this land-use were very old. Many residences had dirt or gravel driveways. Many roof tops had no rain gutters, and many roof tops with rain gutters were connected to lawns.

Therefore, a new model for effective impervious cover was developed, using equation 6.3. This made effective impervious cover a function of the gross impervious cover percentage of single family residential land-use. This change in the model for effective impervious cover produced a substantial reduction in total error for the watershed model. The final values of the calibration coefficients were A0 = 0.90 and A1 = 0.37. For an area which consisted of no single family residential land-use, then SFRIC = 0 and equation 6.3 is reduced to equation 6.2.

6.3.3 Watershed Width

Parameters and coefficients are:

SK, Skewness factor,
EA, Area of subwatershed east of channel,
WA, Area of subwatershed west of channel,
TA, Total area of subwatershed,
WW, Watershed width, and
CL, Channel length.

Equations are:

$SK = |EA - WA| / TA$ Equation 6.4

$WW = (2.0 - SK) * CL$ Equation 6.5

Equations 6.4 and 6.5 were used to compute watershed width. A description of SWMM's usage of watershed width is discussed in SWMM documentation (pp. 96 to 104, SWMM Version 4.1).

Timing of runoff (time of travel of runoff flow) from a watershed can be calibrated in SWMM equally well by calibrating either watershed width, watershed slope, or watershed roughness. Because watershed width and watershed slope were better known constants, they were used without assigning calibration coefficients. Instead, calibration coefficients were assigned to the relatively less well known parameters, such as the Manning's roughness coefficients for pervious and impervious areas.

6.3.4 Manning's Roughness Coefficient for Impervious Areas

Initially, the Manning's roughness coefficient for impervious area was assumed to be 0.020. The final calibrated value of the parameter was 0.0176.

6.3.5 Manning's Roughness Coefficient for Pervious Areas

Parameters and coefficients are:

PR,	Manning's roughness coefficient for pervious area,
GIC,	Percentage of gross impervious cover,
TRC,	Percentage of tree cover, and
A0, A1,	Calibration coefficients.

Equation --

PR = A0 + (A1 * TRC) / (100.0 - GIC) Equation 6.6

Equation 6.6 was used to compute Manning's roughness coefficient for pervious areas. The correction factor for impervious cover is required because tree cover was computed as a fraction of total area, where it was preferred that tree cover be a fraction of total pervious area. It was assumed that the presence of tree cover should slow the runoff rate, effectively increasing the roughness coefficient. The initial values of the calibration coefficients were A0 = 0.20 and A1 = 0.00. The final values of the calibration coefficients were A0 = 0.146 and A1 = 0.160. This would give the parameter a maximum range of 0.146 to 0.306, depending upon the amount of tree cover. The actual range of the parameter was 0.169 to 0.234 with an average of 0.201.

6.3.6 Depression Storage for Pervious Areas

Depression storage for pervious areas was initially assigned a value of 0.15 inch. During initial calibration runs, the value of this parameter tended to approach to zero. However, it was discovered that the total error of the model was not sensitive to this parameter. Therefore, pervious depression storage was assigned a minimal value of 0.10 inch and was left uncalibrated.

6.3.7 Depression Storage for Impervious Areas

Parameters and Coefficients are:

IDS,	Depression storage for impervious areas in inches,
WS,	Watershed slope expressed as percent,
FTC,	Tree cover expressed as a fraction of total area, and
A0, A1,	Calibration coefficients.

Equation --

$$IDS = A0 * (WS \wedge -0.49) + A1 * FTC \qquad \text{Equation 6.7}$$

The relationship of depression storage for impervious areas to slope is discussed in the SWMM documentation (pp. 107 to 110, SWMM Version 4.1). In SWMM, water in the depression storage of pervious areas is detained, but allowed to infiltrate. Water in depression storage of impervious areas is detained, but not allowed to infiltrate. Clearly any water detained in trees will not infiltrate, and therefore some tree areas should be considered as impervious depression storage. A problem with this concept is that water detained in trees should be subtracted from the runoff from pervious areas, rather than subtracted from the runoff from impervious areas. The solution to this problem would be to add another depression storage parameter to SWMM, a non-infiltrating pervious depression storage.

Equation 6.7 was used to compute impervious depression storage, making the parameter a function of slope and tree cover. The initial values of the calibration coefficients were A0 = 0.0303 and A1 = 0.0. The final values of the calibration coefficients were A0 = 0.202 and A1 = 0.164. The values of the IDS parameter ranged from 0.108 inch to 0.194 inch, with an average of 0.156 inch.

This range of values seems to be quite high as compared to values from other SWMM models. However, the total error of the model seemed quite sensitive to these calibration coefficients. Therefore, impervious depression storage was allowed to remain as a calibrated parameter. Pervious and impervious depression storages had the greatest difference between expected and calibrated values than any other parameters in the model.

6.3.8 Impervious Area with Zero Depression Storage

The SWMM input parameter for percentage of impervious area with zero depression storage was initially assigned a value of 25 percent. The final calibrated value of this parameter was 21.25 percent.

6.3.9 Green-Ampt Infiltration Model

Both the Horton and Green-Ampt infiltration models were tried. Eventually, the Green-Ampt infiltration model produced a small improvement in total error for the watershed model, as compared to the Horton infiltration model.

6.3.10 Saturated Hydraulic Conductivity (HYDCON)

Parameters and coefficients are:

SHC, Saturated hydraulic conductivity,
R1, Percent of watershed area with SHC ranging from 0.02 to 0.063 inch per hour,
R2, Percent of watershed area with SHC ranging from 0.063 to 0.20 inch per hour,
R3, Percent of watershed area with SHC ranging from 0.20 to 0.63 inch per hour,
R4, Percent of watershed area with SHC ranging from 0.63 to 2.0 inch per hour, and
A0, Calibration coefficient.

Equations are:

$$SHC = A0 * (0.04*R1 + 0.13*R2 + 0.41*R3 + 1.31*R4) \quad \text{Equation 6.8}$$
$$SHC = 0.036*R1 + 0.117*R2 + 0.369*R3 + 1.179*R4 \quad \text{Equation 6.9}$$

Saturated hydraulic conductivity was computed by Equation 6.8. The initial value of the calibration coefficient was A0 = 1.0. The final value of the calibration coefficient was A0 = 0.90. In this connection Equation 6.8 could be rewritten as Equation 6.9.

It was determined, however, to limit hydraulic conductivity values to less than 1.0 inch per hour, for the extreme case of subwatershed 15. For the watershed model, hydraulic conductivity values ranged from 0.196 to 1.0 inch per hour, with an average value of 0.387 inch per hour.

6.3.11 Initial Soil Moisture Deficit (SMDMAX)

Parameters and coefficient are:

IMD, Initial Moisture Deficit,
C1, Percentage of watershed area with soil texture class of clay,
C2, Percentage of watershed area with soil texture class of clay loam,
C3, Percentage of watershed area with soil texture class of loam,
C4, Percentage of watershed area with soil texture class of silt loam, and
A0, Calibration coefficient.

Equation --

$$IMD = A0 * (0.21*C1 + 0.24*C2 + 0.31*C3 + 0.33*C4) \quad \text{Equation 6.10}$$

Initial moisture deficit was computed by Equation 6.10. The coefficient was obtained from Table 4-10 of the SWMM documentation (p. 118, SWMM Version 4.1). The initial value of the calibration coefficient was A0 = 1.0. The final value of the calibration coefficient was A0 = 0.925. For the watershed model, initial moisture deficit values ranged from 0.198 to 0.239, with an average value of 0.209.

6.3.12 Capillary Suction (SUCT)

Parameters and coefficient are:

CS,	Capillary suction,
C1,	Percentage of watershed area with a soil texture class of clay,
C2,	Percentage of watershed area with a soil texture class of clay loam,
C3,	Percentage of watershed area with a soil texture class of loam,
C4,	Percentage of watershed area with a soil texture class of silt loam, and
A0,	Calibration coefficient.

Equation --

CS = A0 * (7.0*C1 + 10.0*C2 + 8.0*C3 + 8.0*C3) Equation 6.11

Capillary suction was computed by Equation 6.11. These values were obtained from Table 4-11 of the SWMM documentation (p. 119, SWMM Version 4.1). The initial value of the calibration coefficient was A0 = 1.0. The final value of the calibration coefficient was A0 = 0.925. For the watershed model, capillary suction values ranged from 6.86 to 7.70 inch, with an average value of 7.26 inch.

6.4 SWMM Input Parameters for the TRANSPORT Block

6.4.1 Power Function Channels

Parameters and coefficients are:

Q,	Flowrate,
D,	Depth,
E,	Exponent for flow rate versus flow depth relationship, and
P,	Power function exponent.

Approximate flow rate versus flow depth relationships for power function channels:

Type of channel	Exponent	Flowrate to Depth Relationship
Arbitrary	P = arbitrary	Q = D ^ E
Triangular	P = 1	Q = D ^ 2.5
Parabolic	P = 2	Q = D ^ 2.0
Rectangular	P = infinite	Q = D ^ 1.5

Natural channels were modeled as power function channels in the TRANSPORT block (pp. 250 to 253, SWMM Version 4.1). The power function exponent was used to calibrate flow travel time in the main channel by effectively modifying the channel's flow rate versus flow depth relationship. The initial value of the power function exponent was 2.0. The final calibrated value of the power function exponent was 4.0. The cross section of this channel appears approximately trapezoidal. Subsequent to the calibration of the model, it was suggested that adding a second calibration coefficient, in order to make the channel more parabolic near the headwaters and more rectangular near the mouth, would most likely have improved the performance of the model.

6.4.2 Channel Dimensions

Parameters and coefficients are:

CD, Channel depth in feet,
TW, Channel top width in feet, and
WA, Watershed area upstream of channel section in acres.

Equations are:

$$CD = 0.167 * (WA ^ 0.55) \qquad \text{Equation 6.12}$$
$$TW = 2.2 * (WA ^ 0.45) \qquad \text{Equation 6.13}$$

Channel depth was computed by Equation 6.12. Channel top width was computed by Equation 6.13. These equations were derived by regression on channel dimensions from the HEC-2 model (Chan & Associate, 1995).

Except for Manning's roughness coefficient, natural channel dimensions (such as length, slope, depth, and top width) were not calibrated. Table 6.1 contains average, minimum, and maximum values of the uncalibrated natural channel dimensions.

Table 6.1
Uncalibrated Natural Channel Dimensions

	Natural Channel Dimensions				Manning's
	Length	Slope	Top Width	Depth	Roughness
	Feet	Percent	Feet	Feet	Coefficient
Average	1132.3	0.824	59.9	9.6	0.0456
Minimum	312.1	0.419	34.4	4.8	0.0354
Maximum	2454.3	1.974	86.6	14.8	0.0540

6.4.3 Concrete Channel Manning's Roughness Coefficients

The initial value of Manning's roughness coefficient used for concrete channels or pipes was 0.015. The final calibrated value of the parameter was 0.010.

6.4.4 Natural Channel Manning's Roughness Coefficients

Manning's roughness coefficients for natural channels were computed as the length weighted averages of the roughness coefficients of each channel segment taken from the Waller Creek HEC-2 model. Channel flow travel time could be calibrated by calibrating either channel length, channel slope, or channel roughness coefficient. It was decided that since channel length and channel slope were more accurately known, that only the roughness coefficient should be calibrated in the watershed model.

The final calibrated values of Manning's roughness coefficients for natural channels were 0.93 times the values computed from the HEC-2 model. The parameters ranged from 0.0329 to 0.502, with an average value of 0.0424.

Calibrated Manning's roughness coefficients, for both natural channels and concrete channels or pipes, were lower than expected, perhaps compensating for unknown inadequacies of the TRANSPORT block model.

6.5 Model Calibration

The flow data was available for the two in-stream sites from August 31, 1993, to January 14, 1995. This period of approximately 500 days contained 50 rainfall events of greater than 0.10 inches of total rainfall. During this period, 34 storms for Waller Creek @ 38th Street had flow records, and 38 storms for Waller Creek @ 23rd Street had flow records. Of these storms, 25 storms from each site were selected for use in model calibration.

Each calibration run consisted of calibration runs from four continuous periods of time. These four continuous periods were chosen to maximize the total number of large storms, while minimizing the total length of computer time of the calibration run.

For each calibration run, the difference in values of flow between observed and simulated data is computed for a series of rainfall events. No water quality conditions were calibrated. This study developed a statistical water quality model to work with SWMM for continuous simulation.

6.5.1 Error or Objective Function for Calibration

Parameters are:

RE,	Relative Error,
TV,	Total volume,
PF,	Peak flowrate, and
Q,	Instantaneous flowrate.

For each storm the following statistics were computed:

SRETV,	Relative error in total volume for an individual storm,
SREIF,	Relative error in instantaneous flow rate for an individual storm, and
SREPF,	Relative error in peak flowrate for an individual storm.

For all storms the following statistics were computed:

MRETV,	Mean of SRETV,
MREIF,	Mean of SREIF, and
MREPF,	Mean of SREPF.

For all data the following statistics were computed:

RETV,	Relative error in total volume computed on the entire data series,
REIF,	Relative error in flow rate computed on the entire data series, and

SSRIF, Sum of the squares of the residuals between predicted and observed instantaneous values of flow rate.

Equations are:

$$RETV = \left|TV_{Obs} - TV_{Pred}\right| \Big/ \left(\left(TV_{Obs} + TV_{Pred}\right)\Big/2\right) \quad \text{Equation 6.14}$$

$$REPF = \left|PF_{Obs} - PF_{Pred}\right| \Big/ \left(\left(PF_{Obs} + PF_{Pred}\right)\Big/2\right) \quad \text{Equation 6.15}$$

$$REIF = \sum_{i=1}^{i=N}\left|Q_{Obs(i)} - Q_{Pred(i)}\right| \Big/ \left(\left(\left(\sum_{i=1}^{i=N} Q_{Obs(i)}\right) + \left(\sum_{i=1}^{i=N} Q_{Pred(i)}\right)\right)\Big/2\right) \quad \text{Equation 6.16}$$

$$SSRIF = \sum_{i=1}^{i=N}\left|Q_{Obs(i)} - Q_{Pred(i)}\right|^{2} \quad \text{Equation 6.17}$$

Error Function = A1*SSRIF(38) + A2*SSRIF(23) + 10*RETV(38) + 10*RETV(23) + REIF(38) + REIF(23) + MRETV(38) + MRETV(23) + MREPF(38) + MREPF(23) + MREIF(38) + MREIF(23) Equation 6.18

The error function was expressed by Equation 6.18. The numbers 38 and 23 refer to the two sites, Waller Creek @ 38th Street and Waller Creek @ 23rd Street. Both sites were calibrated simultaneously, using the same calibration coefficients for both sites. A1 and A2 were chosen such that their respective terms would each comprise about 25% of the total value of the error function. Thus the SSRIF term accounted for about 50% of the total value of the error function.

The SSRIF term was included in the error function because it was considered to be the best overall evaluator of hydrograph shape. All other terms in the error function were included because they would be eventually be the metrics on which the model would be judged. MRETV, MREPF, and MREIF were included because they provide additional weight to small storms that is not represented by SSRIF, RETV, or REIF.

6.5.2 Minimization of Error Function through Input Variation

The general scheme for calibration of the watershed model was to minimize the error function by varying the 15 calibration coefficients. The calibration scheme could be represented by the following algorithm:

- Execute SWMM.
- Compute the error function.
- Adjust calibration coefficients.
- Repeat until there is no substantial change in the error function.

Computation of the error function and adjustment of the calibration coefficients were implemented by C programs. The entire process was implemented as a DOS batch file. Adjustment of the calibration coefficients was achieved through the following procedure.

- If there is reduction in error function, then:
  - Continue to vary the current parameter by the same amount in the same direction.
  - If there are four consecutive improvements in error function for the current parameter then:
    - Double the increment of change for the current parameter.
- If there is no reduction in error function, then:
  - Change the direction of search for the current parameter.
  - Halve the increment of change for the current parameter.
  - Change the current parameter to the next parameter in the list of parameters.

6.5.3 Model Verification

Except for SSRIF, the same statistics used in the error function of the calibration process were computed for all storms with greater than 0.10 inch in total rainfall. Table 6.2 summarizes the results.

Table 6.2
Relative Error by Storm Classes

	All Storms		Calibrated Storms		Uncalibrated Storms	
Site	38th St.	23rd St.	38th St.	23rd St.	38th St.	23rd St.
Storms	34	38	25	25	9	13
MRETV	0.317	0.182	0.246	0.113	0.513	0.314
MREPF	0.342	0.302	0.304	0.246	0.449	0.409
MREIF	0.489	0.398	0.430	0.314	0.652	0.560
RETV	0.003	0.037	0.000	0.035	0.016	0.048
REIF	0.319	0.265	0.289	0.233	0.454	0.396
	All Storms		Large Storms		Small Storms	
Site	38th St.	23rd St.	38th St.	23rd St.	38th St.	23rd St.
Storms	34	38	18	20	16	18
MRETV	0.317	0.182	0.097	0.089	0.564	0.285
MREPF	0.342	0.302	0.226	0.197	0.473	0.419
MREIF	0.489	0.398	0.291	0.284	0.712	0.525
RETV	0.003	0.037	0.045	0.039	0.351	0.025
REIF	0.319	0.265	0.286	0.237	0.592	0.487

The 23rd Street site was better calibrated than the 38th Street site, probably because the 23rd Street site had higher flow rates. Likewise, large storms were better calibrated than small storms. Worst calibrated were small storms for the 38th Street site, where predicted total volume exceeded observed total volume by 35 percent.

One might believe that the reason for the poor performance of uncalibrated storms as compared to calibrated storms was that uncalibrated storms were excluded from the calibration process. Instead, the actual reason for the poor performance of uncalibrated storms versus calibrated storms was that uncalibrated storms contained a higher percentage of small storms. The set of calibrated storms included 16 large storms and 9 small storms, and the calibration process was designed to enhance the calibration of large storms.

In general, large storms had less relative error than calibrated storms, while uncalibrated storms were had less relative error than small storms. Large storms were defined as those storms having a mean flowrate of 10 cubic feet per second or greater at the 23rd Street site, which corresponds approximately to a total rainfall of 0.50 inch. See the Appendix for sample hydrographs of predicted versus observed flowrate.

6.6 Water Quantity Simulations Using SWMM

Water quantity simulations were run for two time periods and two watershed conditions: The two time periods were:

- Ten years from Jan. 1, 1984, to Dec. 31, 1993, with hourly NWS rainfall data
- 500 days from Aug. 31, 1993, to Jan. 13, 1995, with two minute FEWS rainfall data

The two watershed conditions were:

- Existing conditions
- Option 7, Flood Control Detention Basin Plan (Chan & Associate, 1995)

The ten year simulation had the advantage of a longer period of record, as well as more representative rainfall volumes. The comparison of the rainfall records for the two time periods is shown in Table 6.4. The ten year simulation had the disadvantage of attenuation of peak flow rates caused by the use of hourly rainfall data. The comparison of flow data between the two simulations is shown in Table 6.5.

Except for the relatively large differences in peak flowrate, the two simulations produced very similar results.

Table 6.4
Comparison of Rainfall Records
for 10 Year and 500 Day Simulations

Simulation	10 Year	500 Day
Start date	1/1/84	8/31/93
End date	12/31/93	1/13/95
Number of storm events	395	50
Average duration of storm events in hours	32.1	34.7
Average inter-event period in hours	189.4	209.6
Total rainfall for period (storms >= 0.10 in.)	318.7	38.63
Total rainfall for period (all storms)	328.7	42.29
Average event rainfall in inches	0.807	0.773
Average yearly rainfall in inches (storms >= 0.10 in.)	31.87	28.22
Average yearly rainfall in inches (all storms)	32.87	30.89

Table 6.5
Comparison of 10 Year Water Quantity Simulation
to 500 Day Water Quantity Simulation

10 Year Simulation with Hourly Rainfall 8-31-1993 to 1-14-1995	Reilly School	U. Texas Ath. Field	38^{th} Street	Hemphill Branch	23^{rd} Street	15^{th} Street	Town Lake
	Inlet 06	Inlet 12	Inlet 20	Inlet 34	Inlet 36	Inlet 40	Inlet 46
Watershed area in acres	581	1006	1443	895	2624	3016	3591
Average event peak flowrate in CFS (Existing)	58.8	99.7	114.0	110.4	206.2	251.5	303.1
Average event peak flowrate in CFS (Option 7)	54.6	87.6	96.4	109.1	183.1	233.0	289.1
Average event runoff in MCF (Million Cubic Feet)	0.476	0.843	1.063	0.852	2.126	2.688	3.428
Average event runoff in inches	0.226	0.231	0.203	0.262	0.223	0.245	0.263
Average event runoff coefficient	0.280	0.286	0.251	0.325	0.277	0.304	0.326
Average yearly runoff in MCF (Million Cubic Feet)	18.8	33.3	42.0	33.6	84.0	106.2	135.4
Average yearly runoff in inches	8.92	9.12	8.02	10.36	8.82	9.70	10.39
Average yearly runoff coefficient	0.271	0.277	0.244	0.315	0.268	0.295	0.316
500 Day Simulation with Two Minute Rainfall 1-31-1984 to 12-31-1993	Reilly School	U. Texas Ath. Field	38^{th} Street	Hemphill Branch	23^{rd} Street	15^{th} Street	Town Lake
	Inlet 06	Inlet 12	Inlet 20	Inlet 34	Inlet 36	Inlet 40	Inlet 46
Watershed area in acres	581	1006	1443	895	2624	3016	3591
Average event peak flowrate in CFS (Existing)	86.8	132.4	145.9	166.1	280.6	350.7	418.5
Average event peak flowrate in CFS (Option 7)	73.7	104.0	109.0	165.2	247.0	320.7	393.4
Average event runoff in MCF (Million Cubic Feet)	0.487	0.827	1.033	0.869	2.140	2.735	3.559
Average event runoff in inches	0.231	0.226	0.197	0.267	0.225	0.250	0.273
Average event runoff coefficient	0.299	0.293	0.255	0.344	0.289	0.321	0.351
Average yearly runoff in MCF (Million Cubic Feet)	17.8	30.2	37.7	31.7	78.2	99.9	130.0
Average yearly runoff in inches	8.43	8.27	7.20	9.77	8.21	9.12	9.97
Average yearly runoff coefficient	0.273	0.268	0.233	0.314	0.264	0.293	0.320

7.0 WATER QUALITY MODEL

This study did not adopt the build-up and wash-off algorithm for water quality simulation. There are problems with the use of this algorithm. In the mean time, the study has developed a statistical model to work with SWMM for continuous simulation. This model considers the impacts of both build-up/wash-off and channel bank erosion processes on water quality. The following paragraphs describe the development, calibration, and application of this model.

7.1 Pollutant Parameters

This study developed statistical models for each of the following listed storm water pollutants:

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
FSTR	Fecal Streptococci
TKN	Total Kjeldahl Nitrogen
TPB	Total Lead
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

This study has not developed statistical models for the following pollutant parameters because of lack of relationship between pollutant concentrations and flow rates.

FCOL	Fecal Coliform
NO_2+NO_3	Nitrate plus Nitrite
TOC	Total Organic Carbon

This study has not developed statistical models for the following pollutant parameters because of lack of sufficient data.

DP	Dissolved Phosphorus
NH_3	Ammonia
TCD	Total Cadmium
TCU	Total Copper
TZN	Total Zinc
VSS	Volatile Suspended Solids

7.2 Problems of Water Quality Modeling with SWMM

As described in Section 6.2, there was a problem to develop a reliable build-up function for various pollutant parameters, probably due to the lack of sufficient data to characterize the time series of the build-up and wash-off process. The other difficulty is that there was no algorithm in SWMM to account for the water quality impact of channel bank erosion along Waller Creek.

Sediment transport is a highly important process influencing storm water pollution. Many pollutants, such as phosphorus and organic nitrogen, have substantial solid phases. Other pollutants, such as lead, sorb strongly to sediments. Sources of sediment loading include build-up and wash-off from impervious cover, soil erosion from pervious watershed areas, stream bank erosion, and stream bed scour. SWMM can model build-up, wash-off, and soil erosion in its RUNOFF BLOCK. Stream bed deposition and scour can probably be modeled in the TRANSPORT block. Unfortunately, SWMM contains no model for stream bank erosion.

In the Waller Creek watershed, in-stream concentrations of many pollutants are substantially higher than the measured concentrations coming from individual subwatersheds. In many locations, the stream bed has been scoured to limestone bedrock. On the other hand, unstable stream banks are widespread. In-stream pollutant concentrations are highly correlated to flow rate. Stream bank erosion appears to contribute a significant proportion of the pollutant load in the Waller Creek basin.

The absence of a model for stream bank erosion precluded water quality modeling by SWMM for the Waller Creek watershed. The presence of a high correlation between in-stream pollutant concentrations and flow rate suggested that a statistical water quality model, coupled with a SWMM water quantity model, was capable of modeling in-stream water quality within the Waller Creek watershed.

7.3 Statistical Model Formulation

Parameters and coefficients are:

CONC,	Concentration,
C1,C2,C3,	Multiplicative Coefficients,
A1,A2,A3,	Multiplicative Coefficients,
B1,B2,B3,	Exponential Coefficients,
Rn,	Total rainfall during the preceding in hours, and
Q,	Flow rate.

Statistical analysis of in-stream pollutant concentrations in the Waller Creek basin has shown that the following equation can be well calibrated.

CONC = C1 + (C2 * (Q ^ C3)) Equation 7.1

This statistical model works best within individual rainfall events. Often, the coefficient C2 changes from event to event. Thus C2 is a function of rainfall event or perhaps antecedent conditions. If build-up and wash-off were the predominant effects, then C2 might conceptually represent the amount of pollutant load available on the watershed. However, when the predominant effect is either soil erosion or, especially, stream bank erosion, the concept of build-up no longer explains the variation in C2.

However, it is possible for antecedent conditions to affect the rate of soil or stream bank erosion. If the soil moisture content is high, then soil may be more cohesive and more resistant to erosion. In the Waller Creek watershed, soil is often high in clay content. Clays swell with increased moisture content, which could also explain increased cohesion. According to this hypothesis, the stream bank would be drier and more susceptible to erosion during the rising phase of the hydrograph. Likewise, the stream bank would be wetter and less susceptible to erosion during the falling phase of the hydrograph.

It is reasonable to modify the statistical model of Equation 7.1, such that C2 becomes a function of antecedent conditions. Possible choices for antecedent conditions include variables such as cumulative rainfall or cumulative flow volume. Both have been tried for Waller Creek, giving approximately equal results. For this experiment, cumulative rainfall was chosen over cumulative flow volume, because the record of rainfall was more complete.

For the period of record, from August 10, 1993, to January 14, 1995, values of Rn, the total rainfall occurring over the Waller Creek basin during the previous n hours, were computed for n = 1/4, 1/2, 1, 2, 4, 8, 16, 32, 64, 128, 256, and 512 hours. Various nonlinear statistical models were tried, using all of the rainfall variables listed above. The final choice for C2 as a function of antecedent conditions was Equation 7.2.

$$C2 = A2 + (A3 * \exp(B1 * R64) * (R2 \wedge B2)) \qquad \text{Equation 7.2}$$

For this model, A2, A3, and B2 are usually positive constants; B1 is a negative constant. R2 is the variable, total rainfall for the previous two hours; R64 is the variable, total rainfall for the previous 64 hours. Thus the final version of the nonlinear statistical model is

$$CONC = A1 + ((A2 + (A3 * \exp(B1 * R64) * (R2 \wedge B2))) * (Q \wedge B3)) \qquad \text{Equation 7.3}$$

When there has been no rainfall in the previous two hours, Equation 7.3 reduces to Equation 7.1. As a result, this simplified form of the model is in effect during the falling phase of the hydrograph. Therefore, R2 may help model the differences between the rising and falling phases of the hydrograph. The simplified form of the equation is also in effect when the variable R64 gets very large. Perhaps the expression with R64 helps model cohesion of soil due to moisture content during the rising phase of the hydrograph.

During the preceding discussion, the development of the nonlinear statistical model was presented from a perspective of modeling soil or stream bank erosion. It is also possible to present a similar statistical model, in which a variable similar to R64 models build-up on the watershed, and a variable similar to R2 models wash-off from the watershed. Therefore, the nonlinear statistical model presented here may be capable of modeling build-up, wash-off and erosion as well, depending on the pollutant being modeled.

7.4 Statistical Model Calibration

Because water quality data was collected at two in-stream sites, there were several possibilities in choosing the degrees of freedom for the model. One possibility was to have one model for both sites. Another possibility was to have different models for each site. For the third possibility, the exponential coefficients B1, B2, and B3 could be constrained to have the same values at both sites, while the multiplicative coefficients A1, A2, and A3 were determined independently for each site. These possibilities are specified in Table 7.1.

Table 7.1
Three Water Quality Models with Different Degrees of Freedom

Degrees of Freedom	A1	A2	A3	B1	B2	B3
6	=	=	=	=	=	=
9	<>	<>	<>	=	=	=
12	<>	<>	<>	<>	<>	<>
<> different coefficients at each site				= same coefficients at each site		

For a statistical model, model calibration is equivalent to selecting the model with the highest R Square. Values of R square were computed for the three versions of the water quality model with 6, 9, and 12 degrees of freedom. The results were not significantly different for most of the pollutants. There was one exception; BOD was modeled significantly better by the models with 9 and 12 degrees of freedom. These results are presented in Table 7.2.

Table 7.2
R Square for Three Water Quality Models

Degrees of Freedom	TP	TKN	TN	TSS	TPB	COD	BOD	FSTR
6	0.721	0.645	0.573	0.770	0.872	0.691	0.533	0.616
9	0.723	0.649	0.581	0.786	0.878	0.700	0.581	0.632
12	0.726	0.649	0.583	0.794	0.892	0.705	0.581	0.637

Because there was no significant difference in R square for the three models, the final choice of a model was determined by a subjective evaluation of simulations of the models. A 500 day simulation was run for each of the three models. The model for 38^{th} Street was applied to all sites upstream of 38^{th} Street. The model for 23^{rd} Street was applied to all sites downstream from 23^{rd} Street.

The model with 9 degrees of freedom was selected over the other two models, based on the subjective opinion that it produced the most reasonable simulation.

The model with 6 degrees of freedom had the drawback that mean concentrations for the two gauging stations varied the most from mean concentrations computed by other independent methods.

The model with 12 degrees of freedom had the drawback that predictions for sites upstream from 38th Street were too dissimilar to predictions for sites downstream from 23rd Street. R square and coefficients for the final water quality model are presented in Table 7.3.

Table 7.3
Final Water Quality Model

Waller Creek at 38th Street								
Pollutant	Obs.	R Square	A1	A2	A3	B1	B2	B3
TP	144	0.839	0.1997	0.0532	2.9470	-4.4923	1.8299	0.4696
TKN	133	0.678	0.7775	0.1406	2.8469	-2.9062	0.8468	0.4305
TN	127	0.579	1.7670	0.0730	1.5629	-3.1866	0.7138	0.5379
TSS	140	0.845	15.705	13.145	983.10	-5.1726	2.0000	0.7147
TPB	24	0.906	-21.192	17.319	44.180	-1.6606	0.7784	0.3067
COD	144	0.773	31.433	1.3595	21.365	-2.3503	0.2739	0.6314
BOD	121	0.576	5.4332	0.2119	28.294	-6.0249	1.3422	0.6430
FSTR	112	0.724	-36503	49166	508170	-3.9245	2.0000	0.2238
CONC = A1 + ((A2 + (A3 * exp(B1 * R64) * (R2 ^ B2))) * (Q ^ B3))								
Waller Creek at 23rd Street								
Pollutant	Obs.	R Square	A1	A2	A3	B1	B2	B3
TP	178	0.665	0.2476	0.0387	3.3685	-4.4923	1.8299	0.4696
TKN	171	0.630	0.7678	0.1000	2.9625	-2.9062	0.8468	0.4305
TN	171	0.582	1.7154	0.0370	1.9338	-3.1866	0.7138	0.5379
TSS	175	0.757	21.148	10.038	673.66	-5.1726	2.0000	0.7147
TPB	54	0.868	-0.3863	7.8665	79.269	-1.6606	0.7784	0.3067
COD	177	0.657	35.367	0.4502	24.244	-2.3503	0.2739	0.6314
BOD	170	0.583	7.9396	0.0429	58.524	-6.0249	1.3422	0.6430
FSTR	144	0.550	-4199.1	28648	643507	-3.9245	2.0000	0.2238

7.5 Water Quality Simulations

Water quality simulations were run for two time periods, four watershed conditions, and the eight water quality parameters for which statistical models were developed. The two time periods were:

- Ten years from Jan. 1, 1984, to Dec. 31, 1993, with hourly NWS rainfall data
- 500 days from Aug. 31, 1993, to Jan. 13, 1995, with two minute FEWS rainfall data

The ten year simulation had the advantage of a longer period of record, but the disadvantage of attenuation of peak flow rates caused by the use of hourly rainfall data. The four watershed conditions were:

- Existing conditions
- Tunnel bypass at 15th Street
- Option 7, flood control detention basin plan
- Option 7 detention and tunnel bypass at 15th Street

Tabulations of simulation results are presented in Table 7.4 through Table 7.7.

Table 7.4
10 Year Simulation with Hourly Rainfall
Watershed Mean Concentrations

Existing Conditions		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Reilly School	6	9.9	70.7	2.12	2.86	0.688	375	52.8	92479
U. T. A. F.	12	11.4	83.7	2.39	3.16	0.808	529	64.8	107712
38th Street	20	11.8	85.5	2.40	3.19	0.829	578	67.1	111122
Hemphill Br.	34	12.3	78.3	2.26	2.89	0.786	432	63.4	89923
23rd Street	36	12.7	89.2	2.53	3.15	0.926	686	71.4	101574
15th Street	40	13.1	95.1	2.65	3.27	0.976	767	74.8	105371
Town Lake	46	13.1	99.1	2.72	3.35	1.018	858	76.8	108600
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	11.5	75.2	2.03	2.72	0.692	341	53.7	81646
Tunnel	99	13.8	105.5	3.03	3.59	1.158	1024	89.4	121885
Combined	96+99	12.7	90.1	2.52	3.15	0.921	677	71.3	101446
Detention Basins		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Reilly School	6	9.7	69.2	2.08	2.82	0.676	362	51.9	91557
U. T. A. F.	12	11.1	80.2	2.31	3.08	0.781	496	62.6	105479
38th Street	20	11.3	80.9	2.30	3.09	0.791	530	64.0	107931
Hemphill Br.	34	12.2	77.5	2.23	2.87	0.776	420	62.4	88846
23rd Street	36	12.3	85.2	2.43	3.05	0.886	629	68.1	98866
15th Street	40	12.7	91.6	2.56	3.19	0.942	714	71.9	103094
Town Lake	46	12.9	96.2	2.65	3.28	0.990	810	74.5	106798
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	11.5	74.7	2.02	2.71	0.689	338	53.3	81380
Tunnel	99	13.4	101.0	2.92	3.49	1.113	951	85.8	119020
Combined	96+99	12.4	87.4	2.46	3.09	0.895	636	69.1	99641

Table 7.5
10 Year Simulation with Hourly Rainfall
Pollutant Loads (Town Lake Existing Conditions = 100%)

Existing Conditions		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	%	%	%	%	%	%	%	%
Reilly School	6	10.5	9.9	10.8	11.8	9.4	6.1	9.5	11.8
U. T. A. F.	12	21.5	20.8	21.6	23.2	19.5	15.2	20.7	24.4
38th Street	20	27.9	26.7	27.3	29.5	25.2	20.9	27.1	31.7
Hemphill Br.	34	23.3	19.6	20.6	21.5	19.2	12.5	20.5	20.6
23rd Street	36	60.0	55.9	57.6	58.4	56.4	49.6	57.7	58.0
15th Street	40	78.1	75.2	76.2	76.6	75.2	70.1	76.4	76.1
Town Lake	46	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	44.8	38.5	38.0	41.2	34.5	20.2	35.5	38.2
Tunnel	99	51.8	52.4	54.7	52.8	56.0	58.7	57.3	55.2
Combined	96+99	96.5	90.9	92.7	94.0	90.5	78.9	92.8	93.4
Detention Basins		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	%	%	%	%	%	%	%	%
Reilly School	6	10.3	9.7	10.6	11.7	9.2	5.9	9.4	11.7
U. T. A. F.	12	20.8	19.9	20.9	22.6	18.9	14.2	20.0	23.9
38th Street	20	26.7	25.3	26.2	28.6	24.1	19.2	25.8	30.8
Hemphill Br.	34	23.1	19.4	20.3	21.3	18.9	12.2	20.2	20.3
23rd Street	36	58.1	53.3	55.4	56.5	54.0	45.5	55.0	56.5
15th Street	40	76.2	72.4	73.8	74.6	72.6	65.3	73.4	74.4
Town Lake	46	98.2	97.0	97.5	98.0	97.3	94.5	97.0	98.3
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	45.2	38.8	38.3	41.6	34.9	20.3	35.7	38.6
Tunnel	99	49.6	49.4	52.0	50.5	53.1	53.8	54.2	53.2
Combined	96+99	94.7	88.2	90.3	92.1	87.9	74.1	89.9	91.7

Table 7.6
500 Day Simulation with Two Minute Rainfall
Watershed Mean Concentrations

Existing Conditions		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Reilly School	6	10.7	80.3	2.33	3.05	0.761	456	59.6	98852
U. T. A. F.	12	11.9	90.7	2.53	3.28	0.855	584	69.0	110842
38th Street	20	12.0	90.1	2.49	3.27	0.858	615	69.8	112435
Hemphill Br.	34	12.2	83.5	2.38	3.00	0.848	530	69.8	94860
23rd Street	36	12.8	95.4	2.65	3.27	0.981	767	77.9	105155
15th Street	40	13.0	101.0	2.77	3.39	1.044	894	81.5	109715
Town Lake	46	13.0	104.3	2.86	3.47	1.100	1045	83.5	113754
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	10.8	73.2	2.00	2.67	0.703	407	53.9	82846
Tunnel	99	14.1	117.5	3.31	3.85	1.291	1245	102.7	131259
Combined	96+99	12.4	94.4	2.63	3.24	0.985	809	77.3	106054
Detention Basins		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Reilly School	6	10.3	76.3	2.24	2.97	0.732	420	57.4	96615
U. T. A. F.	12	11.3	84.7	2.41	3.16	0.809	522	65.4	107187
38th Street	20	11.3	83.3	2.35	3.12	0.803	536	65.3	107879
Hemphill Br.	34	12.1	82.4	2.34	2.97	0.835	517	68.4	93515
23rd Street	36	12.3	89.8	2.52	3.13	0.927	688	73.3	101590
15th Street	40	12.6	95.9	2.66	3.27	0.996	820	77.4	106630
Town Lake	46	12.6	100.1	2.76	3.37	1.060	978	80.2	111269
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	10.8	72.8	1.99	2.66	0.700	404	53.5	82573
Tunnel	99	13.5	110.6	3.15	3.69	1.226	1141	97.3	127212
Combined	96+99	12.1	90.7	2.54	3.15	0.949	752	74.2	103659

Table 7.7
500 Day Simulation with Two Minute Rainfall
Pollutant Loads (Town Lake Existing Conditions = 100%)

Existing Conditions		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	%	%	%	%	%	%	%	%
Reilly School	6	11.3	10.5	11.1	12.0	9.5	6.0	9.8	11.9
U. T. A. F.	12	21.3	20.2	20.6	22.0	18.1	13.0	19.2	22.6
38th Street	20	27.0	25.1	25.3	27.4	22.6	17.1	24.2	28.7
Hemphill Br.	34	22.9	19.5	20.3	21.1	18.8	12.4	20.4	20.4
23rd Street	36	59.5	55.0	55.8	56.6	53.7	44.1	56.1	55.6
15th Street	40	77.2	74.4	74.6	75.1	72.9	65.8	75.0	74.1
Town Lake	46	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	43.5	36.5	36.4	40.1	33.3	20.3	33.6	37.9
Tunnel	99	52.3	54.0	55.6	53.2	56.3	57.1	58.9	55.3
Combined	96+99	95.8	90.5	92.0	93.4	89.6	77.4	92.5	93.2
Detention Basins		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	%	%	%	%	%	%	%	%
Reilly School	6	10.9	10.0	10.7	11.7	9.1	5.5	9.4	11.6
U. T. A. F.	12	20.2	18.9	19.6	21.2	17.1	11.6	18.2	21.9
38th Street	20	25.2	23.2	23.8	26.1	21.2	14.9	22.7	27.5
Hemphill Br.	34	22.7	19.3	20.0	20.9	18.5	12.1	20.0	20.1
23rd Street	36	57.0	51.7	53.0	54.3	50.7	39.6	52.7	53.7
15th Street	40	74.5	70.6	71.4	72.4	69.6	60.3	71.2	72.0
Town Lake	46	97.3	95.9	96.6	97.1	96.4	93.6	95.9	97.8
Tunnel Option		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Town Lake	96	43.9	36.8	36.7	40.5	33.6	20.4	33.8	38.3
Tunnel	99	49.4	50.1	52.2	50.3	52.6	51.6	55.0	52.8
Combined	96+99	93.3	86.9	88.9	90.8	86.2	72.0	88.8	91.1

7.6 Contribution of Channel Erosion to Pollutant Concentrations

The City of Austin has conducted extensive monitoring of small watersheds to determine the pollutant concentrations expected for various land-uses. It was possible to model the expected pollutant concentrations of a watershed as a function of the pollutant concentrations coming from each land-use within the watershed. This would result in an estimate of expected pollutant concentrations, assuming there was no substantial in-stream erosion. This estimate from land-use analysis could then be compared to the in-stream estimate computed by the watershed model. The difference between the two estimates would be the contribution from in-stream erosion.

In order to compute watershed pollutant concentrations, as the flow volume weighted mean of the respective land-use pollutant concentrations, it is necessary to estimate the flow volume coming from each land-use. This would be equal to the area of the land-use times the appropriate runoff coefficient. Under the assumption that runoff coefficients are approximately proportional to the percentage of impervious cover, the percentage of impervious area (equal to area multiplied by percentage of impervious cover) could be used as the flow volume weight.

Table 7.8 contains percentages of total impervious area by land-use for seven in-stream locations. In this table, civic land-use was converted to a mixture of office, transportation, and open space land-uses, such that the composite mixture would have the same impervious cover percentage as the civic land-use.

Table 7.9 contains pollutant concentrations for single land-use watersheds, estimated from the COA monitoring data. Single family residential land-use is the mean of Hart Lane, Maple Run, Travis Country Ditch, and Travis Country Pipe sites. Multi-family residential land-use is the mean of Burton Road and Highwood Apartments sites. Commercial land-use is the mean of Barton Creek Square Mall and Barton Ridge sites. Office land-use is the mean of Lavaca Street and Spyglass Office sites. Industrial land-use is represented by the Metric Boulevard site. Open Space land-use is the mean of Bear Creek and Windago Way sites. Transportation land-use is represented by the Jollyville Road site.

Table 7.10 contains pollutant concentrations estimated for seven Waller Creek in-stream sites. Table 7.10 is computed from Table 7.8 and Table 7.9 by matrix multiplication, followed by division by 100 per cent. Table 7.11 contains the estimates of percentage of pollutant concentrations due to in-stream erosion. Table 7.11 was computed as the difference of Table 7.10 and Table 7.6 (existing conditions), expressed as a percentage of Table 7.10.

Table 7.8
Percentage of Total Impervious Area by Land-Use for Waller Creek In-Stream Locations

	Inlet 06	Inlet 12	Inlet 20	Inlet 34	Inlet 36	Inlet 40	Inlet 46
Single Fam. Res.	37.43	35.22	42.97	23.13	35.02	28.90	24.90
Multi-Fam. Res.	7.23	6.80	8.08	18.60	12.05	10.12	8.45
Commercial	30.55	28.66	22.62	13.73	17.60	15.95	16.88
Office	3.33	12.81	12.72	30.18	21.30	27.86	27.23
Industrial	18.37	11.61	8.64	0.61	4.77	3.91	4.34
Open Space	1.94	2.42	2.65	3.54	3.07	2.95	3.16
Transportation	1.15	2.47	2.32	10.22	6.20	10.31	15.04

Table 7.9
Pollutant Concentrations for Single Land-Use Watersheds from COA Monitoring

	BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Single Fam. Res.	9.91	45.04	1.150	1.748	0.313	172.9	19.86	46946
Multi-Fam. Res.	11.11	61.44	1.119	1.522	0.318	178.3	14.74	42070
Commercial	11.37	85.86	1.552	2.072	0.358	257.1	24.09	43707
Office	11.28	82.54	1.523	2.159	0.304	86.7	38.68	50862
Industrial	10.85	61.17	1.476	1.985	0.464	286.1	21.34	59492
Open Space	5.58	30.46	0.604	0.947	0.085	104.8	3.57	11210
Transportation	6.06	62.65	1.105	1.573	0.243	323.1	47.96	48615

Table 7.10
Pollutant Concentrations for Waller Creek In-Stream Locations Predicted by COA Small Watershed Monitoring

		BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Location	Inlet	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Mg/L	Ug/L	Col/100Ml
Reilly School	6	10.53	62.83	1.332	1.870	0.349	217.3	21.69	47364
U. T. A. F.	12	10.49	64.61	1.334	1.882	0.335	201.6	23.61	46819
38th Street	20	10.39	61.78	1.298	1.850	0.328	192.9	23.14	46494
Hemphill Br.	34	10.20	66.39	1.290	1.830	0.303	173.1	27.47	45758
23rd Street	36	10.27	63.60	1.292	1.841	0.315	182.6	25.31	46228
15th Street	40	10.15	65.67	1.307	1.859	0.310	180.8	27.73	46633
Town Lake	46	9.95	66.42	1.307	1.854	0.308	189.5	29.04	46719

Table 7.11
Percentage of Pollutant Concentrations Attributed to Channel Erosion for Waller Creek In-Stream Locations

Location	Inlet	BOD	COD	TKN	TN	TP	TSS	Lead	Fec. Strep.
Reilly School	6	1.46	21.77	42.73	38.74	54.10	52.32	63.64	52.09
U. T. A. F.	12	11.82	28.77	47.28	42.71	60.78	65.48	65.80	57.76
38th Street	20	13.70	31.42	47.84	43.45	61.81	68.66	66.85	58.65
Hemphill Br.	34	16.16	20.51	45.74	38.94	64.23	67.33	60.64	51.76
23rd Street	36	19.80	33.36	51.27	43.63	67.84	76.17	67.51	56.04
15th Street	40	21.94	34.95	52.88	45.12	70.27	79.78	65.96	57.50
Town Lake	46	23.19	36.35	54.25	46.54	72.04	81.87	65.24	58.93

As expected, the percentage of pollutant concentration attributed to in-stream erosion was highest for total suspended solids. Total phosphorus and total lead had the second and third highest percentages.

8.0 WATERSHED RETROFIT PLANS

The data from monitoring and watershed simulation indicates that the channel and bank erosion may have played a significant role in elevating pollutant levels in Waller Creek. While implementing structural control measures in the upland will provide some water benefits, the retrofit of infrastructures within the stream of Waller Creek is more important in water quality improvement.

8.1 Existing Watershed Retrofit Conditions

<u>Structural Controls</u>: The COA has funded the implementation of a wet pond at Guadalupe and 38th Streets. This pond serves as a flood and water quality control detention basin which receives drainage from a 156-acre area. The City coordinated the construction of this pond in connection with a commercial development. As part of the City's urban watershed retrofit program, the construction of this pond is about to be complete. This pond will treat all storm water discharges from the 156-acre drainage area. The treatment efficiency of the structure can be estimated from Table 3.1. The City has not implemented other major structures or channel projects in Waller Creek for water quality benefit.

<u>Non-Structural Controls</u>: The COA has implemented a city-wide community education program for storm water pollution control. This program consists of several elements including public awareness surveys, citizen monitoring projects, storm water pollution posters, environmental hotline, and storm drain stenciling projects. This education program has covered the Waller Creek basin, however, the effectiveness of the program cannot be quantified at this time. In addition to the education program, the COA has a Storm Water Discharge Permit Program for targeted business and industries in the City. This program complies with a City Code for water quality protection. The program issues permit and conducts annual inspections of the permitted sites. The inspection evaluates site maintenance and check s the storage, handling, and disposal of the waste materials in order to prevent illegal discharges to the storm sewers. The targeted facilities include automobile-related business, machine shops, and mobile washing units. The COA monitored the oil/grit separator of an auto repair and storage facility at 45th street and Duval Boulevard. The separator was too small to treat storm water discharged from this site. Nevertheless, the tests of storm water discharges to and from the separator indicate that the pollutant levels of the discharges are not significantly higher than those of the discharges from the average commercial/industrial areas. These test results show that the City's permit program may have positive impacts on the quality of storm water discharged from these businesses and industries.

8.2 Existing Watershed Management Plans for the Waller Creek Basin

As described in Section 2.6, the COA has recently completed two studies for the Waller Creek basin. Chan and Associates (Chan, 1995) conducted a basin-wide flood management study. This study (option 7) proposes the implementation of 4 flood control detention basins and the improvement of some sections and channels of Waller Creek.

Table 8.1
Summary of Retrofit Plan Proposals

Retrofit Plan	General Description	Construction Cost (Million Dollars)	Annual Maintenance Cost (Thousand Dollars)
Flood Management Plan for upper Waller Creek basin above 15th St.	Chan Study, Option 7 -- Consturct flood control (FC) detention basins.	3.2	20
Alternative to Option 7	Modify 4 FC detention basins to dry or wet ponds.	4.0	24
Flood Management Plan for lower Waller Creek basin below 15th St. -- Flow diversion by tunnel	Loomis Study -- Construct 18 to 20 foot diameter, 5500 foot tunnel from 15th St. to Town Lake.	15-18	53
Channel projects for Waller Creek	Chan and Loomis Studies -- Repair and construct channel and banks of 67 sections.	3.0	20
Water Quality (WQ) retrofit plan for lower basin	Loomis Study -- Implement a flow-balancing method device in Town Lake.	1.0-1.75	unknown
WQ retrofit plan for upper basin	Implement 12 WQ control ponds and structures in the upper basin.	1.1	9.3

In addition to this study, the COA further committed to develop overall Waller Creek flood and water quality management plans in order to comply with the requirements for business development in the downtown area. The City hired a consultant, Loomis and Associates (Loomis, 1996), to develop plans for Waller Creek flood management and water quality improvement. The City's Waller Creek basin grant team was directed to provide water quality and in-stream, continuous storm water flow data to the consultant for the plan development. Loomis and Associates has completed Phase I study of a three phase project. This project will provides planning and engineering design for flood control measures in the downtown area and for basin-wide water quality enhancement. The phase I study proposed an 18 to 20-foot diameter, 5,500 feet long flow diversion tunnel for flood control, in-stream erosion control, and various structural and non-structural BMPs for basin-wide water quality improvement. This study also proposed to construct a flow balancing method (FBM) device to treat the storm water discharged from the diversion channel.

Table 8.1 is a summary of the proposals presented by the consultants, Chan and Loomis.

8.3 Retrofit Plans Evaluation

This study evaluates the water quality benefits of retrofits for the Waller Creek basin for several basin retrofit plans, including the existing retrofit condition, the detention basin plan (Option 7 plan), the flow diversion tunnel design, and a recommendation of this grant study. This study conducted continuous hydrologic and water quality simulation using SWMM and a statistical model. These models were calibrated and verified using data collected from the COA Storm Water Monitoring Program. Storm water flow and water quality conditions at the mouth of Waller Creek and at the outlet of each subwatershed were simulated for each retrofit plan scenario. Tables 7.4-7.7 present values of storm water pollutant concentrations for various locations and for different watershed retrofit plan conditions. Table 8.2 presents values of storm water pollutant loads to Town Lake from Waller Creek for different watershed retrofit plan conditions.

Assume the pollutant loading index for Town Lake location for the existing retrofit condition is 100 percent, a watershed simulation corresponding to a retrofit plan would provide a new pollutant loading index less or equal to 100 percent. The results of the watershed simulation corresponding to each retrofit plan condition are presented below and in Table 8.3.

- Suppose the COA will implement 4 flood control detention basins in the Waller Creek basin according to the Option 7 plan, the loading index for this plan will be 93 to 97 percent, varying with pollutant parameters. In other words, the flood control retrofit plan would benefit the water quality condition by a reduction of loading of 3 to 7 percent at the mouth of Waller Creek. The reason for the reduction of loading is that the flow rates of storm water discharges in the Waller Creek channels would be generally decreased due to the implementation of flood control detention ponds, and in turn, the channel bed and bank erosions would be decreased.

Table 8.2
Annual Pollutant Load to Town Lake
from Waller Creek for Various Retrofit Options
from 500 Day Simulation

A. Annual Pollutant Load to Town Lake without Tunnel Diversion								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	Pounds	Pounds	Colonies	Pounds	Pounds	Pounds	Pounds	Pounds
Existing	1.05E+5	8.47E+5	4.19E+15	6.78E+2	2.32E+4	2.81E+4	8.92E+3	8.48E+6
Option 7	1.02E+5	8.12E+5	4.09E+15	6.50E+2	2.24E+4	2.73E+4	8.60E+3	7.94E+6
Dry Ponds	9.43E+4	7.20E+5	3.68E+15	5.82E+2	2.01E+4	2.48E+4	7.82E+3	7.33E+6
Wet Ponds	9.59E+4	7.69E+5	3.84E+15	6.28E+2	2.11E+4	2.54E+4	8.23E+3	7.92E+6
B. Annual Pollutant Load to Town Lake with Tunnel Diversion								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	Pounds	Pounds	Colonies	Pounds	Pounds	Pounds	Pounds	Pounds
Existing	1.01E+5	7.66E+5	3.90E+15	6.27E+2	2.13E+4	2.63E+4	7.99E+3	6.56E+6
Option 7	9.81E+4	7.35E+5	3.81E+15	6.02E+2	2.06E+4	2.55E+4	7.70E+3	6.10E+6
Dry Ponds	8.98E+4	6.48E+5	3.41E+15	5.34E+2	1.83E+4	2.30E+4	6.95E+3	5.57E+6
Wet Ponds	9.15E+4	6.90E+5	3.56E+15	5.78E+2	1.92E+4	2.35E+4	7.32E+3	6.05E+6
C. Annual Pollutant Load to Town Lake with Tunnel Diversion and Flow Balance								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	Pounds	Pounds	Colonies	Pounds	Pounds	Pounds	Pounds	Pounds
Existing	7.32E+4	5.38E+5	2.75E+15	4.27E+2	1.49E+4	1.88E+4	5.48E+3	4.14E+6
Option 7	7.21E+4	5.23E+5	2.71E+15	4.15E+2	1.46E+4	1.85E+4	5.35E+3	3.92E+6
Dry Ponds	6.73E+4	4.67E+5	2.43E+15	3.70E+2	1.30E+4	1.68E+4	4.86E+3	3.56E+6
Wet Ponds	6.47E+4	4.69E+5	2.42E+15	3.84E+2	1.30E+4	1.62E+4	4.88E+3	3.75E+6

Table 8.3
Pollutant Loads from Waller Creek for Various Retrofit Options Expressed as Percentage of Load for Existing Conditions from 500 Day Simulation

A. Annual Pollutant Load to Town Lake without Tunnel Diversion								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	%	%	%	%	%	%	%	%
Existing	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Option 7	97.33	95.85	97.78	95.91	96.57	97.13	96.35	93.61
Dry Ponds	89.65	85.08	87.98	85.90	86.68	88.04	87.67	86.49
Wet Ponds	91.24	90.85	91.68	92.64	90.84	90.19	92.26	93.37

B. Annual Pollutant Load to Town Lake with Tunnel Diversion								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	%	%	%	%	%	%	%	%
Existing	95.79	90.51	93.23	92.50	92.03	93.36	89.57	77.40
Option 7	93.28	86.85	91.09	88.77	88.89	90.78	86.24	71.97
Dry Ponds	85.43	76.57	81.55	78.76	79.12	81.82	77.83	65.70
Wet Ponds	87.06	81.52	84.94	85.25	82.96	83.65	81.97	71.30

C. Annual Pollutant Load to Town Lake with Tunnel Diversion and Flow Balance								
Condition	BOD	COD	Fec. Strep.	Lead	TKN	TN	TP	TSS
	%	%	%	%	%	%	%	%
Existing	69.64	63.53	65.57	63.05	64.24	66.74	61.44	48.85
Option 7	68.59	61.82	64.69	61.28	62.81	65.64	59.92	46.19
Dry Ponds	63.97	55.13	58.09	54.61	56.27	59.82	54.43	42.04
Wet Ponds	61.51	55.35	57.85	56.60	55.90	57.68	54.65	44.20

- One alternative plan to "Option 7" is to modify all 4 detention basins to wet or dry ponds by raising the level of crest of the service spillway. In this connection, the emergency spillway of each detention basin may have to be widened in order to provide adequate discharge capacity for the protection of the dam. Assume the ponds have the average treatment efficiency of a wet or dry pond, the loading index for this alternative is 86 to 90 percent for an all dry pond plan and 91 to 93 percent for an all wet pond plan.

- Assuming that the diversion tunnel, instead of "Option 7" or its alternative, will be installed, the overall index of loading (including loads carried by the discharge of diversion and loads at the mouth of Waller Creek) will be about 77 to 96 percent. The reduction of the loading is due to the fact that the flows below the diversion point will not exceed 50 cfs, and in turn, the low flows will significantly decrease the erosion for the reach below the diversion. Further, if a multi-chamber, flow-balancing device will also be installed at the outlet of the diversion tunnel and if the device will have a treatment efficiency of about 50 percent for all considered pollutant parameters, the loading index can be reduced to 49 to 70 percent. With the addition of an Option 7 alternative plan to the described tunnel diversion plus flow-balancing device program, i.e., a dry-pond flood control plan will also be implemented, the loading index can be further reduced to 42 to 64 percent.

- In the average, at least 50 percent of the storm water pollution in the Waller Creek basin was caused by channel bed and bank erosions. The studies of Chan and Loomis have identified a total of 67 erosion sites along the banks of Waller Creek, ranging from 10 to 250 feet. Channel projects such as the construction of gabions, and rock or concrete riprap along these eroded channels should provide substantial water quality benefits. These benefits and the impacts of the channel projects on flooding condition cannot be quantified without additional monitoring and modeling program. Nevertheless, by realizing their benefits to water quality, these channel projects should be implemented in conjunction with any flood control or water quality retrofit plan.

8.4 Retrofit Plan Recommendation

Section 8.3 provides a quantification of water quality benefit for each specified watershed retrofit plan. These benefits can be further quantified as the reduction of pollutant load for a specified pollutant parameter. In addition, Table 8.1 specified the costs for each component of the retrofit plans. Based on the above described cost and benefit analyses, this report presents the following retrofit plan recommendation.

- This recommendation complies with the plan of the Loomis study, i.e., constructing a flow diversion tunnel between 15th Street and Town Lake. The diversion will prevent flooding in the downtown area and make this area feasible for business development. The diversion will improve the quality of storm water entering Town Lake by about 4 to 23 percent, varying with the type of pollutant parameter. At a lesser priority, the flow-balancing device can be installed at the outlet of the diversion. This installation will further improve the quality of water entering Town Lake by a total of about 36 percent.

- Channel projects to reduce bank erosions should be implemented. These projects can provide substantial water quality benefits although these benefits cannot be quantified. It is recommended that the COA should implement a monitoring and modeling program to quantify the impacts and benefits of the identified channel projects.

- The Option 7 plan should be implemented in order to improve flood control in the upper Waller Creek basin. All flood control detention basins under Option 7 plan should be modified to dual purpose ponds (dry or wet pond) in order to create additional water quality benefits.

- Existing non-structural control BMPs for the Waller Creek basin such as community education, Storm Water Discharge Permit and Inspection, dry weather screening, and street inlet filter trap programs should be maintained. Nevertheless, the effectiveness of these programs should be further evaluated.

- Other than those water quality control BMPs required for new development or re-development, the City should probably not implement additional retrofit ponds or BMPs in the upper land of the Waller Creek basin. An addition of a water quality control pond or structure in the upper land provides little water quality benefit in considering its small contributing area and the relatively low level of pollution generated by wash-off from the area (as compared to the impacts of channel erosion).

9.0 CONCLUSIONS OF STUDY

This grant study implemented a storm water monitoring program for the Waller Creek basin. This program established 2 in-stream monitoring stations and 5 BMP inflow-outflow testing stations. The COA monitored storm rainfall events at these stations in the past three years. Using data collected from the monitoring program as well as from the City's GIS application, this study developed and calibrated the SWMM and a statistical water quality model for the Waller Creek basin. The Study further runs continuous watershed simulations for alternative retrofit plan conditions. The following paragraphs summarize data, model development, and results of watershed simulation of this study.

- The Waller Creek basin is a fully urbanized watershed located in the center of Austin, Texas. The storm water data collected by the Waller Creek monitoring program provides additional information on the flow and quality conditions of storm water discharged from the Austin's urban core. This data further confirms that the impacts of urban development on the water quality of streamflow are two-fold. The pollutant concentrations and loads discharged from the drainage basin of a creek generally increase with increasing urban development in the basin. In addition, the channel and bank erosions will increase with increased flow rates resulting from higher basin imperviousness, and in turn, increase the concentration of pollutants in the stream.

- On the average, the channel and bank erosions contributed about 50 percent of loads or concentrations of pollutants carried by the storm water discharges in Waller Creek, ranging from about 70-80 percent for TP and TSS to 20-40 percent for BOD and COD. The storm water runoff from the drainage basin contributed about another 50 percent of pollutants in the storm water discharges in Waller Creek. This is generally true for other urban creeks in the Austin area.

- This study implemented the EPA Storm Water Management Model (SWMM) and developed a statistical water quality model for the Waller Creek basin. Through continuous watershed simulation using these models, this study was able to quantify the quality and quantity conditions of storm water discharges at various locations within the Waller Creek basin. This study has conducted simulations for different watershed management scenarios. The models used in this study can be applied to other urban watersheds in Austin as well as in areas of other municipalities.

- This study recommends the construction of a flow diversion tunnel as specified in the Loomis study (Loomis and Associates, 1996). Not only will this diversion protect the downtown business area from flooding, but it will significantly improve the quality of storm water entering Town Lake due to less bank erosion between the diversion and Town Lake. Additional channel projects to reduce bank erosions will further improve the quality of storm water in Waller Creek. Nevertheless, this study recommends that the COA should implement a monitoring and modeling program to quantify the impacts and benefits of these channel projects.

- This study also recommends the implementation of flood control detention basins in the upper Waller Creek basin as specified in the "Option 7" plan in the Chan study (Chan and Associates, 1995). This study recommends, however, to modify all four detention basins into dual purpose ponds (dry or wet ponds). Based on continuous simulation, this modification is considered feasible.

- Based on limited data, this study considers that some existing BMPs such as; community education, dry weather screening, Storm Water Discharge Permit Program, and inlet filter traps, are effective to control storm water pollution. It is necessary, however, to collect additional data in order to quantify the effectiveness of these programs.

- Wet ponds, sand filtration, and grassed channels are all effective in detaining storm water pollution. Oil/grit separators with adequate storage are good devices for pre-treatment. The COA requires the installation of these BMPs for most new development or re-development in the urban watersheds. This study, however, does not recommend additional retrofit plan to implement such BMPs in the upper land of the Waller Creek basin. An addition of water quality control structures in the upper land provides little water quality benefit in considering its small contributing area and the low level of pollution generated by the wash-off from this area.

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500 Day Simulation
Existing Conditions
FEWS Rainfall

```
*    NBLOCK  JIN(1)  JOUT(1)  JIN(2)  JOUT(2)
SW     2       0        9       9       0
*    NITCH  NSCRAT(1)  NSCRAT(2)  NSCRAT(3)  NSCRAT(4)  NSCRAT(5)  NSCRAT(6)
MM     6       11         12         13         14         15         16
@    11   'D:\SWMM\WALLER\RAIN\FEWS9395.INT'
@     9   'RUNOFF.INT'
*
$RUNOFF
*
A1   'WALLER CREEK 500 DAY SIMULATION - EXISTING CONDITIONS'
A1   '08/31/93 TO 01/14/95'
*    METRIC  ISNOW  NRGAG  INFILM  KWALTY  IVAP  NHR  NMN  NDAY  MONTH  IYRSTR
B1     0       0      9       1       0      3    00   00   31    08     93
*    IPRN(1)  IPRN(2)  IPRN(3)
B2     1         1        0
*    WET  WETDRY  DRY    LUNIT   LONG
B3   120    480   86400    4    950114
*    PCTZER   REGEN
B4    21.25  0.01000
*    ROPT
D1     1
*    EVAPORATION RATES
*    NVAP(1)  NVAP(2)
F1     93       36
*    YEARS 1993 TO 1995 ARE AVERAGE VALUES
*      JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
F2   2.7945 3.1395 4.6575 5.2670 5.9570 7.3485 8.1995 7.9235 5.9915 4.7610 3.2545 2.5760 93
F2   2.7945 3.1395 4.6575 5.2670 5.9570 7.3485 8.1995 7.9235 5.9915 4.7610 3.2545 2.5760 94
F2   2.7945 3.1395 4.6575 5.2670 5.9570 7.3485 8.1995 7.9235 5.9915 4.7610 3.2545 2.5760 95
*
```

*	NAMEG	NGTO	NPG	GWIDTH	GLEN	GSLOPE	SSL	SSR	GROUGH	DFULL	DSTART
G1	101	4	4	20.0	7560.18	0.01112	0.0	0.0	0.04650	4.0	0.0
G1	301	4	4	25.0	3326.50	0.00974	0.0	0.0	0.04650	4.5	0.0
G1	1501	14	2	4.0	4346.73	0.01923	0.0	0.0	0.01000	0.0	0.0
G1	1701	18	2	2.5	3136.20	0.02200	0.0	0.0	0.01000	0.0	0.0
G1	2301	24	4	15.0	2497.43	0.01550	0.0	0.0	0.04650	3.5	0.0
G1	2501	26	2	5.0	5845.23	0.01103	0.0	0.0	0.01000	0.0	0.0

*

*	JK	1	2	3	4	5	6	7	8	9
*	FEWS	2410	2230	3120	3100	2400	3110	3130	3123	3000

*

*	JK	NAMW	NGTO	WWIDTH	WAREA	IMPERV	WSLOPE	IROUGH	PROUGH	ISTOR	PSTOR	SUCT	HYDCON	SMDMAX
H1	1	1	101	9629	218.7	37.06	0.01587	0.0176	0.1777	0.1597	0.10	7.270	0.3631	0.2024
H1	2	3	301	7665	231.7	29.71	0.02035	0.0176	0.1861	0.1589	0.10	7.161	0.3180	0.2011
H1	3	5	5	2776	130.4	39.00	0.02254	0.0176	0.1917	0.1620	0.10	6.864	0.1958	0.1981
H1	3	7	7	2677	115.5	48.88	0.02673	0.0176	0.1941	0.1578	0.10	6.873	0.2243	0.1996
H1	3	9	9	4432	236.5	34.98	0.02901	0.0176	0.1976	0.1594	0.10	7.037	0.3167	0.2026
H1	4	11	11	3253	73.1	22.18	0.03095	0.0176	0.1706	0.1178	0.10	7.059	0.3193	0.2024
H1	4	13	13	4177	122.0	27.94	0.02293	0.0176	0.2268	0.2119	0.10	7.111	0.4606	0.2122
H1	4	15	1501	8632	127.0	21.26	0.02994	0.0176	0.2300	0.2050	0.10	7.704	1.0000	0.2387
H1	4	17	1701	4876	32.6	19.22	0.03206	0.0176	0.2340	0.2079	0.10	7.157	0.8576	0.2304
H1	4	19	19	7253	155.1	17.03	0.04436	0.0176	0.2009	0.1483	0.10	7.546	0.2893	0.2103
H1	8	21	21	9312	225.4	22.89	0.04575	0.0176	0.2290	0.1878	0.10	7.369	0.3457	0.2050
H1	5	23	2301	3986	92.6	44.04	0.01305	0.0176	0.1690	0.1588	0.10	7.064	0.2785	0.2001
H1	6	25	2501	11317	155.8	42.70	0.01660	0.0176	0.1713	0.1480	0.10	7.365	0.2960	0.2086
H1	6	27	27	9870	263.9	40.22	0.01514	0.0176	0.1856	0.1739	0.10	7.285	0.2620	0.2079
H1	7	29	29	2908	68.8	38.70	0.02965	0.0176	0.2192	0.1897	0.10	7.325	0.4894	0.2233
H1	7	31	31	2115	116.9	40.86	0.03434	0.0176	0.2345	0.2060	0.10	7.248	0.3474	0.2023
H1	7	33	33	5485	196.7	42.22	0.03594	0.0176	0.2142	0.1749	0.10	7.311	0.3576	0.2057
H1	8	35	35	1131	60.9	62.19	0.05026	0.0176	0.2007	0.1439	0.10	7.284	0.3690	0.2023
H1	8	37	37	4826	322.7	63.70	0.04509	0.0176	0.1991	0.1451	0.10	7.284	0.3690	0.2023
H1	9	39	39	3753	70.0	66.26	0.05016	0.0176	0.1926	0.1322	0.10	7.284	0.3690	0.2023
H1	9	41	41	1957	159.3	58.71	0.04584	0.0176	0.1911	0.1330	0.10	7.324	0.3344	0.2054
H1	9	43	43	5133	236.5	58.60	0.04928	0.0176	0.2154	0.1657	0.10	7.457	0.2185	0.2154
H1	9	45	45	4297	178.6	56.90	0.02026	0.0176	0.2000	0.1792	0.10	7.557	0.5185	0.2207

```
*
*   NPRNT  INTERV
M1    0       1
*
$TRANSPORT
*
A1  'WALLER CREEK 500 DAY SIMULATION - EXISTING CONDITIONS'
A1  '08/31/93 TO 01/14/95'
*    NDT   NINPUT  NNYN  NNPE  NOUTS  NPRINT  NPOLL  NITER  IDATEZ  METRIC  INTPRT
B1  180360   0      0     4     0       1      0      6       0       0       1
*    DT     EPSIL   DWDAYS  TZERO    GNU    TRIBA
B2  240  0.000001    0.0    0.0   0.00001   0.0
*   NCNDTRL  NINFIL  NFILTH  NDESN
B3     0        1       0      0
*   NKLASS  KPRINT
C1     0      0
*   NOE    NUE(1) NUE(2) NUE(3) NTYPE   DIST    GEOM1   SLOPE    ROUGH   GEOM2 BARREL GEOM3
E1  46     4601     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4601   45       0      0     15   1251.6   14.832  0.6144  0.04593  86.56    1    4.000
E1  45     4501     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4501   44       0      0     15   1251.6   14.622  0.6008  0.04608  85.56    1    4.000
E1  44     4401     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4401   43       0      0     15   1489.6   14.342  0.7855  0.03925  84.22    1    4.000
E1  43     4301     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4301   42       0      0     15   1489.6   14.056  0.8385  0.03672  82.84    1    4.000
E1  42     4201     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4201   41       0      0     15    618.6   13.861  0.4187  0.04711  81.90    1    4.000
E1  41     4101     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4101   40       0      0     15    618.6   13.664  0.6725  0.04774  80.95    1    4.000
E1  40     4001     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  4001   39       0      0     15    962.5   13.576  0.6276  0.04185  80.52    1    4.000
E1  39     3901     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  3901   38       0      0     15    962.5   13.488  0.4662  0.03822  80.09    1    4.000
E1  38     3801     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
E1  3801   37       0      0     15   1370.7   13.077  0.8335  0.04269' 78.09    1    4.000
E1  37     3701     0      0     19      0.0    0.000  0.0000  0.00000   0.00    0    0.000
```

E1	3701	36	0	0	15	1370.7	12.655	1.0512	0.04380	76.02	1	4.000
E1	36	3601	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	3601	35	0	0	15	411.4	12.574	0.7426	0.04622	75.62	1	4.000
E1	35	3501	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	3501	22	0	0	15	411.4	12.492	1.1621	0.04613	75.22	1	4.000
E1	22	2201	34	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2201	21	0	0	15	2454.3	9.492	0.5487	0.04352	60.08	1	4.000
E1	21	2101	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2101	20	0	0	15	2454.3	9.107	0.9780	0.04659	58.08	1	4.000
E1	20	2001	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2001	19	0	0	15	1613.6	8.835	1.0082	0.04873	56.66	1	4.000
E1	19	1901	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1901	18	0	0	15	1613.6	8.555	0.6404	0.03850	55.18	1	4.000
E1	18	1801	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1801	14	0	0	15	526.0	8.435	1.2525	0.03674	54.55	1	4.000
E1	14	1401	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1401	13	0	0	15	1331.2	7.714	1.0525	0.03859	50.71	1	4.000
E1	13	1301	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1301	12	0	0	15	1331.2	7.469	0.5578	0.04287	49.38	1	4.000
E1	12	1201	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1201	11	0	0	15	879.3	7.318	0.8890	0.05022	48.57	1	4.000
E1	11	1101	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1101	10	0	0	15	879.3	7.165	0.5979	0.04752	47.73	1	4.000
E1	10	1001	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1001	9	0	0	15	1355.2	6.652	0.7386	0.03701	44.92	1	4.000
E1	9	901	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	901	8	0	0	15	1355.2	6.101	0.7205	0.03599	41.85	1	4.000
E1	8	801	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	801	7	0	0	15	799.1	5.817	0.7327	0.03488	40.25	1	4.000
E1	7	701	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	701	6	0	0	15	799.1	5.522	0.7931	0.03497	38.57	1	4.000
E1	6	601	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	601	5	0	0	15	991.2	5.172	0.6728	0.03292	36.56	1	4.000
E1	5	501	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	501	4	0	0	15	991.2	4.801	1.0678	0.03664	34.40	1	4.000
E1	4	0	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000

```
E1  34    3401    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  3401  33      0     0   15  1758.9   6.568  0.7740  0.04650  44.46   1   4.000
E1  33    3303    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  3303  3302    0     0   15   312.1   6.489  1.2449  0.04650  44.01   1   4.000
E1  3302  3301    0     0   15   838.9   6.271  0.4768  0.04650  42.80   1   4.000
E1  3301  32      0     0   15   607.9   6.109  1.9741  0.04650  41.90   1   4.000
E1  32    3201    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  3201  31      0     0    2   770.8   5.000  1.4826  0.01000  14.20   1   0.000
E1  31    3101    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  3101  30      0     0    2   770.8   5.000  0.7230  0.01000  14.20   1   0.000
E1  30    3001    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  3001  29      0     0    2   663.8   5.417  0.9792  0.01000   9.00   1   0.000
E1  29    2901    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  2901  28    9926    0    2   944.9   4.333  1.4288  0.01000   9.00   1   0.000
E1  28    2802    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  2802  2801    0     0    2  1643.8   5.417  0.8395  0.01000   6.50   1   0.000
E1  2801  27      0     0    2   930.8   4.833  0.6769  0.01000   4.00   1   0.000
E1  27    2703    0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  2703  2702    0     0    1  1252.1   4.000  0.3834  0.01000   0.00   1   0.000
E1  2702  2701    0     0   14   838.2   3.500  1.6226  0.04650  22.20   1   0.000
E1  2701  9924    0     0   14  1031.8   3.500  0.5331  0.04650  22.20   1   0.000
E1  9924  24      0     0   22     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  24     0      0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  9926  26      0     0   22     0.0   0.000  0.0000  0.00000   0.00   0   0.000
E1  26     0      0     0   19     0.0   0.000  0.0000  0.00000   0.00   0   0.000
*
*   9924 Existing School for the Blind Detention Pond
*   LOUT(IS)
G1     0
*   TSDEP      TSAREA      TSTORE   TSQOU
G2   0.00         0.0         0.0     0.0
G2   0.60     14520.0      4356.0    10.0
G2   1.60     63888.0     43560.0    20.0
G2   2.60    141715.2    146361.6    40.0
G2   3.60    180628.8    307533.6    58.0
G2   4.60    198343.2    497019.6    70.0
```

```
G2   5.60  218961.6  705672.0   80.0
G2   6.10  227818.8  817367.1   83.0
G2   6.35  232247.4  874875.4  156.0
G2   6.60  236676.0  933490.8  491.0
*   STOREL(IS)
G5     0.0
*
*   9926 Central Park Detention Pond
*   LOUT(IS)
G1     0
*   TSDEP      TSAREA     TSTORE  TSQOU
G2   0.00         0.0        0.0    0.0
G2   1.00     34848.0    17424.0   28.0
G2   2.00     52272.0    60984.0  125.0
G2   3.00     69696.0   121968.0  191.0
G2   4.00    113256.0   213444.0  251.0
G2   5.00    148104.0   344124.0  366.0
G2   5.50    156816.0   420354.0  443.0
G2   6.00    165528.0   500940.0  528.0
G2   7.00    172062.0   669735.0  722.0
G2   8.00    178596.0   845064.0  942.0
*   STOREL(IS)
G5     0.0
*
J1  20  36  40  46
*   DINFIL  GINFIL  RINFIL  RSMAX
K1  0.0001    0.0     0.0    0.0
K2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
$ENDPROGRAM
```

10 Year Simulation
Option 7 Detention Ponds
NWS Rainfall

```
*    NBLOCK   JIN(1)   JOUT(1)   JIN(2)   JOUT(2)
SW     2        0         9         9        0
*    NITCH   NSCRAT(1)   NSCRAT(2)   NSCRAT(3)   NSCRAT(4)   NSCRAT(5)   NSCRAT(6)
MM     6        11          12          13          14          15          16
@    11   'D:\SWMM\WALLER\RAIN\NWS4294.INT'
@     9   'D:\RUNOFF.INT'
*
$RUNOFF
*
A1   'WALLER CREEK - 10 YEAR SIMULATION'
A1   '01/01/84 TO 01/01/94'
*    METRIC   ISNOW   NRGAG   INFILM   KWALTY   IVAP   NHR   NMN   NDAY   MONTH   IYRSTR
B1     0        0       1        1        0       3     00    00    01     01      84
*    IPRN(1)   IPRN(2)   IPRN(3)
B2     1         1         0
*    WET   WETDRY   DRY    LUNIT    LONG
B3   120    480    86400     4     931231
*    PCTZER   REGEN
B4    21.25  0.01000
*    ROPT
D1     1
*    EVAPORATION  RATES
*    NVAP(1)  NVAP(2)
F1     84       120
*    YEAR 1993 HAS AVERAGE VALUES
*       1      2      3      4      5      6      7      8      9      10     11     12
F2   2.3460 3.9675 5.4050 7.5670 8.4870 7.4750 8.6595 8.6020 6.4745 3.5880 3.4040 1.9320 84
F2   2.5415 1.9205 3.6800 4.7955 6.3825 6.7620 7.7050 8.9355 6.7735 4.3700 2.1735 2.2425 85
F2   2.9900 3.4960 5.3820 4.9105 4.7610 5.7270 8.6480 6.9345 4.5310 3.6570 2.8060 1.6330 86
F2   2.0010 2.9670 4.8760 6.5090 4.9450 6.1640 7.1760 7.7855 6.5320 5.5545 3.3235 2.3805 87
F2   3.1970 3.4385 5.2440 5.5430 6.6815 8.1420 7.2680 7.8430 6.0835 2.7485 4.5540 3.0015 88
F2   2.3115 1.7365 4.7265 6.0835 6.9805 7.7395 8.9585 8.4755 7.4175 7.0150 3.8870 2.4610 89
```

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F2  3.7030 3.8065 3.8755 4.8990 7.6130 9.8440 8.7515 8.5675 6.0260 5.4395 3.1510 3.5305 90
F2  2.0355 3.3465 5.3475 5.0370 6.0030 7.3715 7.8890 7.8315 4.9220 6.4745 3.3005 3.4960 91
F2  2.9325 2.8520 4.5310 4.9795 6.2330 7.9925 8.5675 8.0730 7.0610 5.8650 3.9675 2.4265 92
F2  2.7945 3.1395 4.6575 5.2670 5.9570 7.3485 8.1995 7.9235 5.9915 4.7610 3.2545 2.5760 93
*
*   NAMEG  NGTO  NPG  GWIDTH    GLEN     GSLOPE    SSL  SSR   GROUGH   DFULL  DSTART
G1   101    4     4    20.0    7560.18  0.01112   0.0  0.0  0.04650   4.0     0.0
G1   301    4     4    25.0    3326.50  0.00974   0.0  0.0  0.04650   4.5     0.0
G1  1501   14     2     4.0    4346.73  0.01923   0.0  0.0  0.01000   0.0     0.0
G1  1701   18     2     2.5    3136.20  0.02200   0.0  0.0  0.01000   0.0     0.0
G1  2301   24     4    15.0    2497.43  0.01550   0.0  0.0  0.04650   3.5     0.0
G1  2501   26     2     5.0    5845.23  0.01103   0.0  0.0  0.01000   0.0     0.0
*
*   JK NAMW NGTO WWIDTH WAREA IMPERV  WSLOPE IROUGH PROUGH  ISTOR PSTOR SUCT  HYDCON SMDMAX
H1  1    1   101   9629 218.7 37.06 0.01587 0.0176 0.1777 0.1597 0.10 7.270 0.3631 0.2024
H1  1    3   301   7665 231.7 29.71 0.02035 0.0176 0.1861 0.1589 0.10 7.161 0.3180 0.2011
H1  1    5     5   2776 130.4 39.00 0.02254 0.0176 0.1917 0.1620 0.10 6.864 0.1958 0.1981
H1  1    7     7   2677 115.5 48.88 0.02673 0.0176 0.1941 0.1578 0.10 6.873 0.2243 0.1996
H1  1    9     9   4432 236.5 34.98 0.02901 0.0176 0.1976 0.1594 0.10 7.037 0.3167 0.2026
H1  1   11    11   3253  73.1 22.18 0.03095 0.0176 0.1706 0.1178 0.10 7.059 0.3193 0.2024
H1  1   13    13   4177 122.0 27.94 0.02293 0.0176 0.2268 0.2119 0.10 7.111 0.4606 0.2122
H1  1   15  1501   8632 127.0 21.26 0.02994 0.0176 0.2300 0.2050 0.10 7.704 1.0000 0.2387
H1  1   17  1701   4876  32.6 19.22 0.03206 0.0176 0.2340 0.2079 0.10 7.157 0.8576 0.2304
H1  1   19    19   7253 155.1 17.03 0.04436 0.0176 0.2009 0.1483 0.10 7.546 0.2893 0.2103
H1  1   21    21   9312 225.4 22.89 0.04575 0.0176 0.2290 0.1878 0.10 7.369 0.3457 0.2050
H1  1   23  2301   3986  92.6 44.04 0.01305 0.0176 0.1690 0.1588 0.10 7.064 0.2785 0.2001
H1  1   25  2501  11317 155.8 42.70 0.01660 0.0176 0.1713 0.1480 0.10 7.365 0.2960 0.2086
H1  1   27    27   9870 263.9 40.22 0.01514 0.0176 0.1856 0.1739 0.10 7.285 0.2620 0.2079
H1  1   29    29   2908  68.8 38.70 0.02965 0.0176 0.2192 0.1897 0.10 7.325 0.4894 0.2233
H1  1   31    31   2115 116.9 40.86 0.03434 0.0176 0.2345 0.2060 0.10 7.248 0.3474 0.2023
H1  1   33    33   5485 196.7 42.22 0.03594 0.0176 0.2142 0.1749 0.10 7.311 0.3576 0.2057
H1  1   35    35   1131  60.9 62.19 0.05026 0.0176 0.2007 0.1439 0.10 7.284 0.3690 0.2023
H1  1   37    37   4826 322.7 63.70 0.04509 0.0176 0.1991 0.1451 0.10 7.284 0.3690 0.2023
H1  1   39    39   3753  70.0 66.26 0.05016 0.0176 0.1926 0.1322 0.10 7.284 0.3690 0.2023
H1  1   41    41   1957 159.3 58.71 0.04584 0.0176 0.1911 0.1330 0.10 7.324 0.3344 0.2054
H1  1   43    43   5133 236.5 58.60 0.04928 0.0176 0.2154 0.1657 0.10 7.457 0.2185 0.2154
```

```
H1   1   45     45   4297  178.6  56.90  0.02026 0.0176 0.2000 0.1792 0.10 7.557 0.5185 0.2207
*
*    NPRNT   INTERV
M1     0         1
*
$TRANSPORT
*
A1   'WALLER CREEK - 10 YEAR SIMULATION'
A1   '01/01/84 TO 01/01/94'
*     NDT      NINPUT  NNYN   NNPE   NOUTS   NPRINT  NPOLL   NITER   IDATEZ   METRIC   INTPRT
B1   1315080      0       0      4      0        1      0       6       0        0        1
*     DT     EPSIL    DWDAYS  TZERO     GNU     TRIBA
B2   240  0.000001     0.0     0.0    0.00001    0.0
*    NCNDTRL  NINFIL  NFILTH  NDESN
B3     0        1       0      0
*    NKLASS   KPRINT
C1     0        0
*
*    NOE    NUE(1) NUE(2) NUE(3) NTYPE    DIST     GEOM1    SLOPE     ROUGH    GEOM2  BARREL  GEOM3
E1   46     4601     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4601   45       0      0     15     1251.6   14.832   0.6144   0.04593   86.56     1     4.000
E1   45     4501     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4501   44       0      0     15     1251.6   14.622   0.6008   0.04608   85.56     1     4.000
E1   44     4401     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4401   43       0      0     15     1489.6   14.342   0.7855   0.03925   84.22     1     4.000
E1   43     4301     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4301   42       0      0     15     1489.6   14.056   0.8385   0.03672   82.84     1     4.000
E1   42     4201     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4201   41       0      0     15      618.6   13.861   0.4187   0.04711   81.90     1     4.000
E1   41     4101     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4101   40       0      0     15      618.6   13.664   0.6725   0.04774   80.95     1     4.000
E1   40     4001     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4001   39       0      0     15      962.5   13.576   0.6276   0.04185   80.52     1     4.000
E1   39     3901     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   3901   38       0      0     15      962.5   13.488   0.4662   0.03822'  80.09     1     4.000
E1   38     3801     0      0     19        0.0    0.000   0.0000   0.00000    0.00     0     0.000
```

E1	3801	37	0	0	15	1370.7	13.077	0.8335	0.04269	78.09	1	4.000
E1	37	3701	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	3701	36	0	0	15	1370.7	12.655	1.0512	0.04380	76.02	1	4.000
E1	36	3601	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	3601	35	0	0	15	411.4	12.574	0.7426	0.04622	75.62	1	4.000
E1	35	3501	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	3501	22	0	0	15	411.4	12.492	1.1621	0.04613	75.22	1	4.000
E1	22	2201	34	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2201	21	0	0	15	2454.3	9.492	0.5487	0.04352	60.08	1	4.000
E1	21	2101	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2101	20	0	0	15	2454.3	9.107	0.9780	0.04659	58.08	1	4.000
E1	20	9920	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	9920	2001	0	0	22	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	2001	19	0	0	15	1613.6	8.835	1.0082	0.04873	56.66	1	4.000
E1	19	1901	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1901	18	0	0	15	1613.6	8.555	0.6404	0.03850	55.18	1	4.000
E1	18	1801	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1801	14	0	0	15	526.0	8.435	1.2525	0.03674	54.55	1	4.000
E1	14	1401	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1401	13	0	0	15	1331.2	7.714	1.0525	0.03859	50.71	1	4.000
E1	13	1301	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1301	12	0	0	15	1331.2	7.469	0.5578	0.04287	49.38	1	4.000
E1	12	9912	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	9912	1201	0	0	22	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1201	11	0	0	15	879.3	7.318	0.8890	0.05022	48.57	1	4.000
E1	11	1101	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1101	10	0	0	15	879.3	7.165	0.5979	0.04752	47.73	1	4.000
E1	10	1001	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	1001	9	0	0	15	1355.2	6.652	0.7386	0.03701	44.92	1	4.000
E1	9	901	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	901	8	0	0	15	1355.2	6.101	0.7205	0.03599	41.85	1	4.000
E1	8	801	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	801	7	0	0	15	799.1	5.817	0.7327	0.03488	40.25	1	4.000
E1	7	701	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000
E1	701	6	0	0	15	799.1	5.522	0.7931	0.03497	38.57	1	4.000
E1	6	9906	0	0	19	0.0	0.000	0.0000	0.00000	0.00	0	0.000

```
E1  9906   601     0    0   22     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1   601   5       0    0   15   991.2  5.172  0.6728  0.03292  36.56  1  4.000
E1   5     501     0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1   501   4       0    0   15   991.2  4.801  1.0678  0.03664  34.40  1  4.000
E1   4     0       0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  34     3401    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  3401   33      0    0   15  1758.9  6.568  0.7740  0.04650  44.46  1  4.000
E1  33     3303    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  3303   3302    0    0   15   312.1  6.489  1.2449  0.04650  44.01  1  4.000
E1  3302   3301    0    0   15   838.9  6.271  0.4768  0.04650  42.80  1  4.000
E1  3301   32      0    0   15   607.9  6.109  1.9741  0.04650  41.90  1  4.000
E1  32     3201    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  3201   31      0    0    2   770.8  5.000  1.4826  0.01000  14.20  1  0.000
E1  31     3101    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  3101   30      0    0    2   770.8  5.000  0.7230  0.01000  14.20  1  0.000
E1  30     3001    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  3001   29      0    0    2   663.8  5.417  0.9792  0.01000   9.00  1  0.000
E1  29     2901    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  2901   28   9926    0    2   944.9  4.333  1.4288  0.01000   9.00  1  0.000
E1  28     2802    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  2802   2801    0    0    2  1643.8  5.417  0.8395  0.01000   6.50  1  0.000
E1  2801   27      0    0    2   930.8  4.833  0.6769  0.01000   4.00  1  0.000
E1  27     2703    0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  2703   2702    0    0    1  1252.1  4.000  0.3834  0.01000   0.00  1  0.000
E1  2702   2701    0    0   14   838.2  3.500  1.6226  0.04650  22.20  1  0.000
E1  2701   9924    0    0   14  1031.8  3.500  0.5331  0.04650  22.20  1  0.000
E1  9924   24      0    0   22     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  24     0       0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  9926   26      0    0   22     0.0  0.000  0.0000  0.00000   0.00  0  0.000
E1  26     0       0    0   19     0.0  0.000  0.0000  0.00000   0.00  0  0.000
*
*   9920 Hancock Golf Course Detention Pond
*   LOUT(IS)
G1    0
*   TSDEP     TSAREA     TSTORE   TSQOU
G2   0.00        0.0        0.0     0.0
```

```
G2    2.00    17859.6     17859.6     90.0
G2    4.00    35283.6     71002.8    240.0
G2    6.00    52272.0    158558.4    440.0
G2    8.00    60984.0    271814.4    650.0
G2   10.00   117612.0    450410.4    850.0
G2   12.00   129808.8    697831.2   1030.0
G2   13.00   210612.6    868041.9   1100.0
G2   14.00   291416.4   1119056.4   1200.0
G2   15.00   308187.0   1418858.1   1250.0
G2   16.00   324957.6   1735430.4   1310.0
G2   18.00   358498.8   2418886.8   2212.0
G2   20.00   392040.0   3169425.6   3820.0
*    STOREL(IS)
G5      0.0
*    9912 U. T. Athletic Field Detention Pond
*    LOUT(IS)
G1      0
*    TSDEP      TSAREA      TSTORE    TSQOU
G2    0.00        0.0         0.0      0.0
G2    2.00    71002.8     71002.8    204.0
G2    4.00   170755.2    312760.8    552.0
G2    6.00   373309.2    856825.2    876.0
G2    8.00   494841.6   1724976.0   1116.0
G2    9.00   544500.0   2244646.8   1514.0
G2   10.00   594158.4   2813976.0   2140.0
G2   12.00   656013.6   4064148.0   3808.0
*    STOREL(IS)
G5      0.0
*    9906 Revised Reilly School Detention Pond
*    LOUT(IS)
G1      0
*    TSDEP      TSAREA      TSTORE    TSQOU
G2    0.00        0.0         0.0      0.0
G2    1.50    20328.0     15246.0    100.0
G2    2.50    89443.2     70131.6    160.0
G2    3.50   169303.2    199504.8    312.0
```

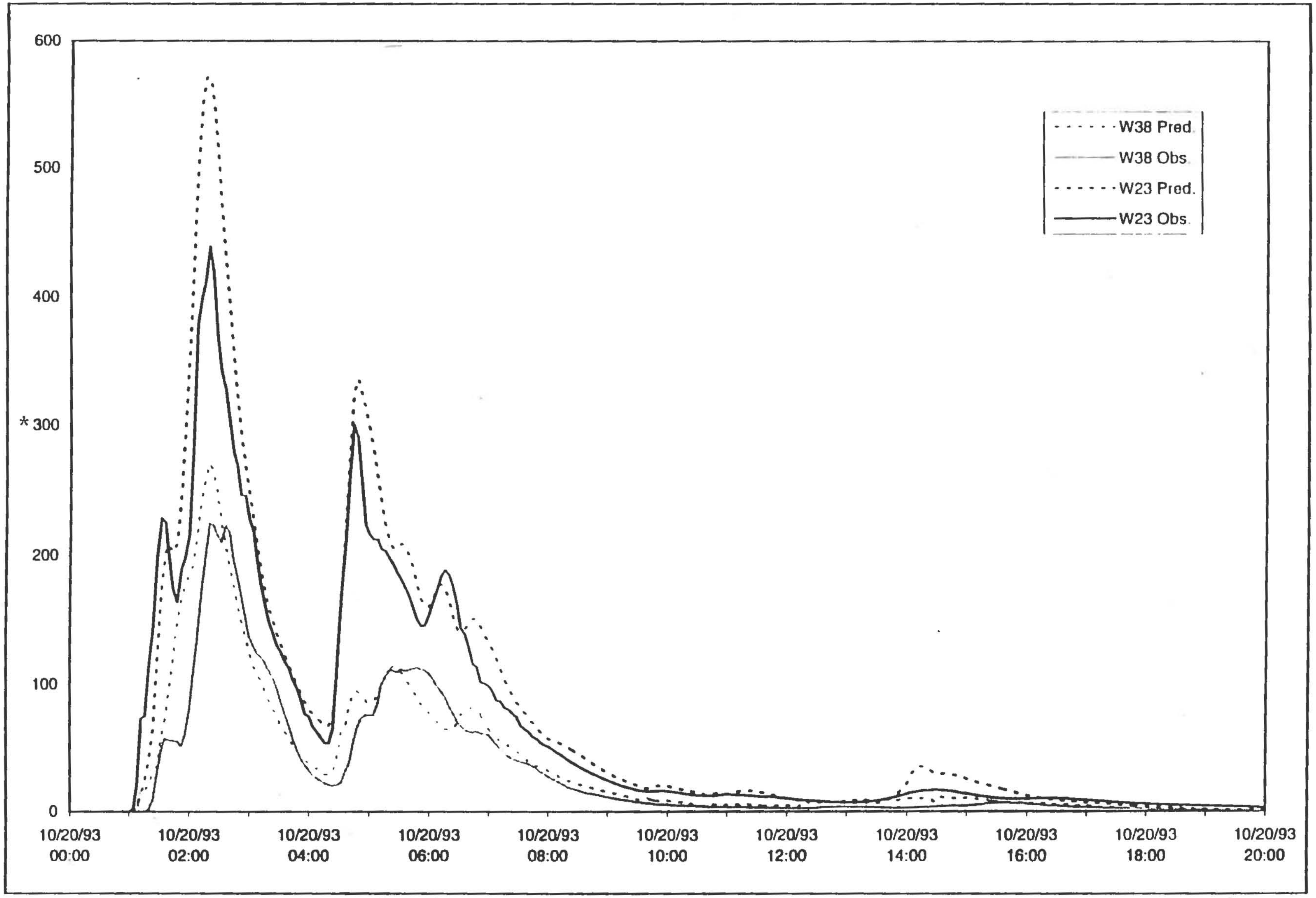
```
G2    5.50  276751.2   645559.2   620.0
G2    7.50  295627.2  1217937.6   900.0
G2    8.50  303758.4  1517630.4  1040.0
G2    9.00  314793.6  1672268.4  1080.0
G2    9.50  324667.2  1832133.6  1120.0
G2   10.00  332217.6  1996354.8  1303.0
G2   10.50  340348.8  2164496.4  1530.0
G2   11.00  349641.6  2336994.0  1833.0
G2   11.50  357772.8  2513847.6  2180.0
*    STOREL(IS)
G5      0.0
*    9924 Expanded School for the Blind Detention Pond
*    LOUT(IS)
G1      0
*    TSDEP     TSAREA      TSTORE  TSQOU
G2    0.00        0.0         0.0    0.0
G2    0.50     1742.4       435.6    4.0
G2    1.50    20037.6     11325.6    7.0
G2    2.50    59241.6     50965.2   14.0
G2    3.50   106286.4    133729.2   18.0
G2    4.50   121968.0    247856.4   22.0
G2    5.50   129808.8    373744.8   24.0
G2    6.50   139392.0    508345.2   25.0
G2    8.50   164656.8    809344.8   26.0
G2    9.50   177724.8    980535.6   27.0
G2   11.50   201247.2   1359072.0   28.0
G2   12.50   214315.2   1566853.2   28.5
G2   13.00   223462.8   1676297.7   28.7
G2   13.50   232610.4   1790316.0  102.0
G2   14.00   250470.0   1911086.1  237.0
G2   14.50   268329.6   2040786.0  412.0
*    STOREL(IS)
G5      0.0
*    9926 Central Park Detention Pond
*    LOUT(IS)
G1      0
```

```
*    TSDEP     TSAREA     TSTORE   TSQOU
G2    0.00        0.0        0.0     0.0
G2    1.00    34848.0    17424.0    28.0
G2    2.00    52272.0    60984.0   125.0
G2    3.00    69696.0   121968.0   191.0
G2    4.00   113256.0   213444.0   251.0
G2    5.00   148104.0   344124.0   366.0
G2    5.50   156816.0   420354.0   443.0
G2    6.00   165528.0   500940.0   528.0
G2    7.00   172062.0   669735.0   722.0
G2    8.00   178596.0   845064.0   942.0
*    STOREL(IS)
G5      0.0
*
J1   20   36   40   46
*    DINFIL   GINFIL   RINFIL   RSMAX
K1   0 0001     0.0      0.0      0.0
K2   0 0   0.0   0.0   0.0   0.0   0 0   0.0   0.0   0.0   0.0   0.0   0.0
$ENDPROGRAM
```

Tunnel Option
Cards Substituted in TRANSPORT Block

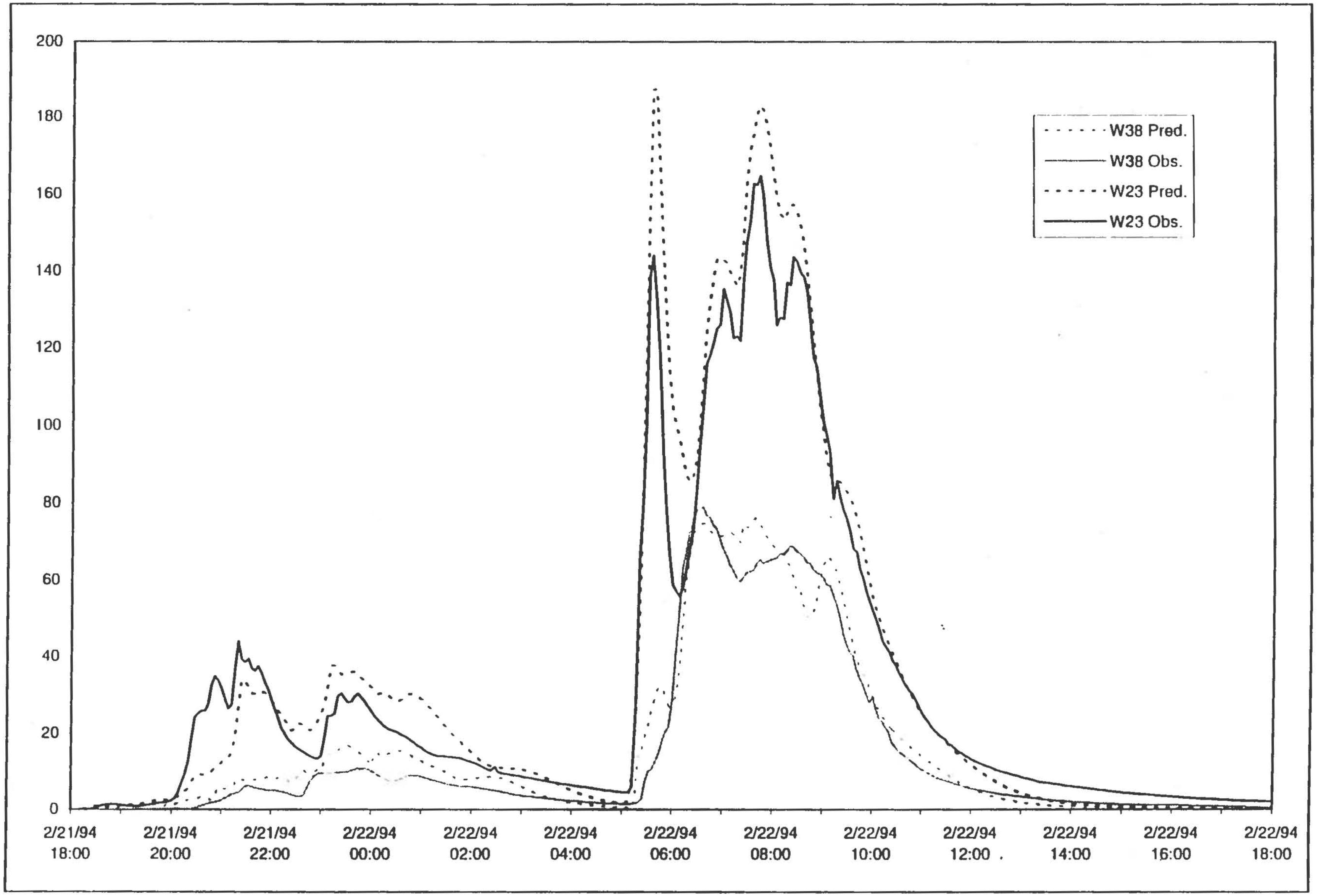
```
*    NOE    NUE(1)  NUE(2)  NUE(3)  NTYPE    DIST    GEOM1    SLOPE    ROUGH    GEOM2  BARREL  GEOM3
E1   4201   41         0       0      15    618.6   13.861   0.4187   0.04711   81.90     1     4.000
E1   41     4101       0       0      19      0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4101   9940       0       0      15    618.6   13.664   0.6725   0.04774   80.95     1     4.000
E1   99     9940       0       0      19      0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   9940   40         0       0      21      0.0   50.000   0.0000   0.00000    0.00     0      4101
E1   40     4001       0       0      19      0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   4001   39         0       0      15    962.5   13.576   0.6276   0.04185   80.52     1     4.000
E1   39     3901       0       0      19      0.0    0.000   0.0000   0.00000    0.00     0     0.000
E1   3901   38         0       0      15    962.5   13.488   0.4662   0.03822   80.09     1     4.000
```

Appendix B
Observed and Predicted Hydographs

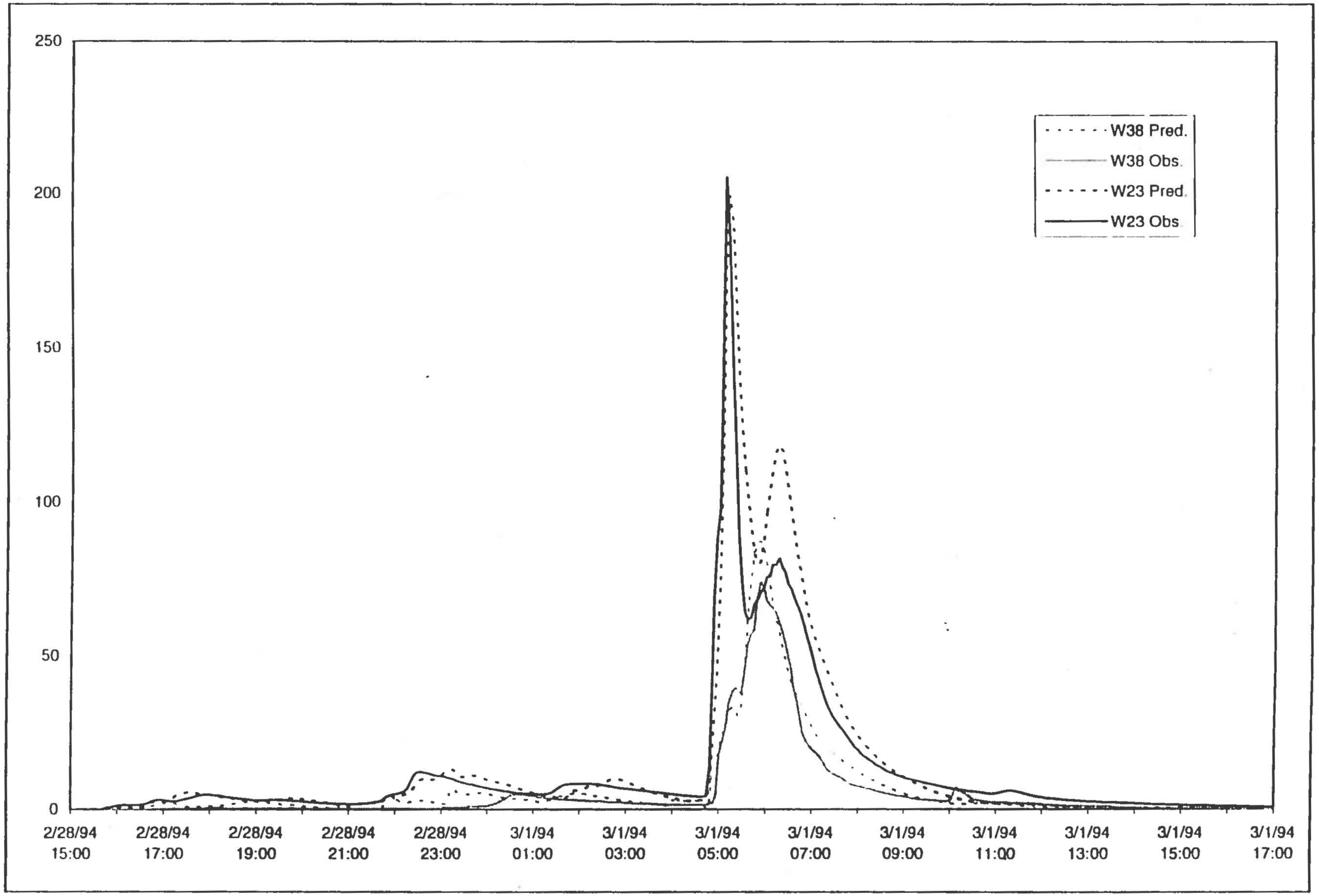


* Values are discharges in cubic feet per second.

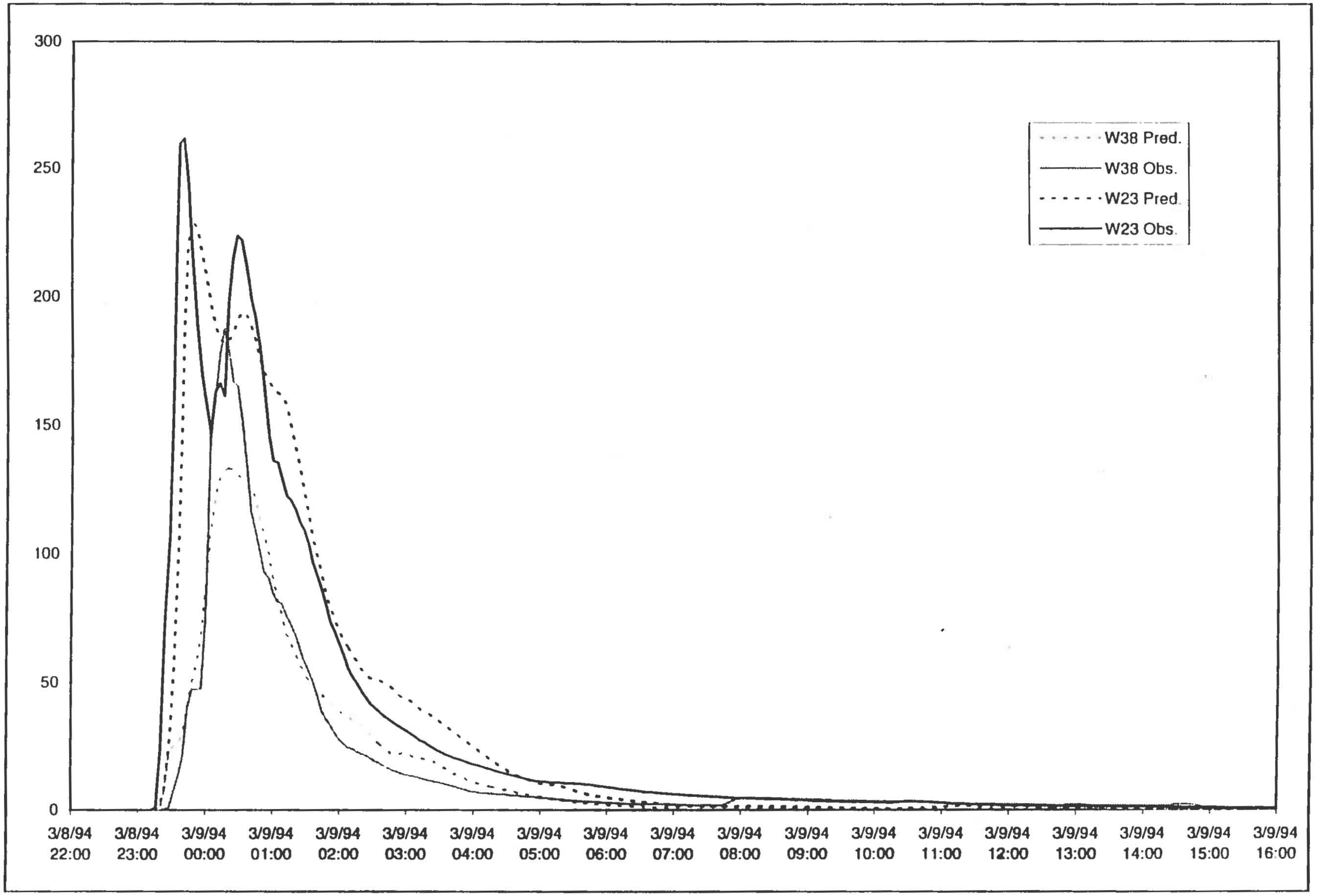
Appendix B
Observed and Predicted Hydographs



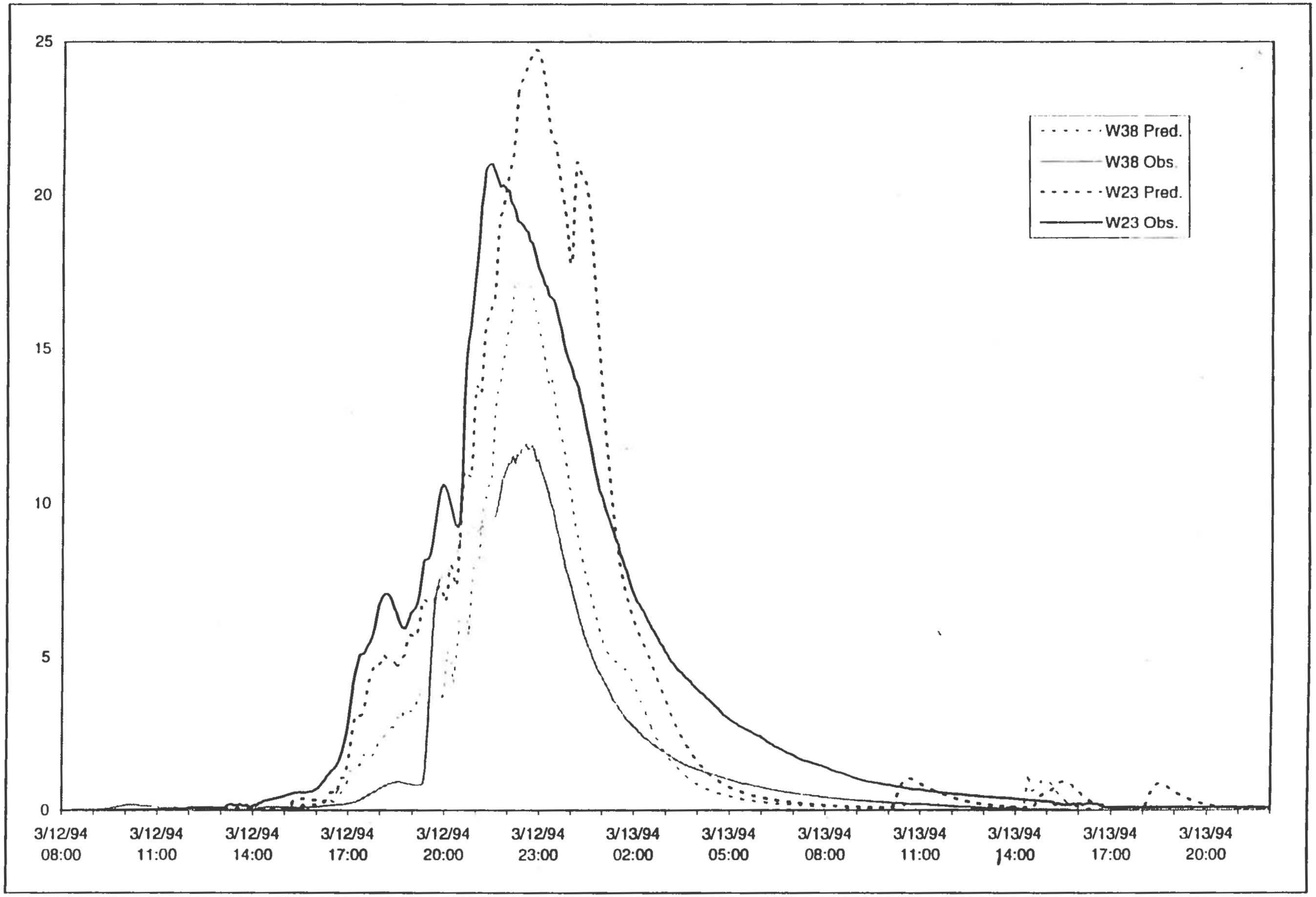
Appendix B
Observed and Predicted Hydographs



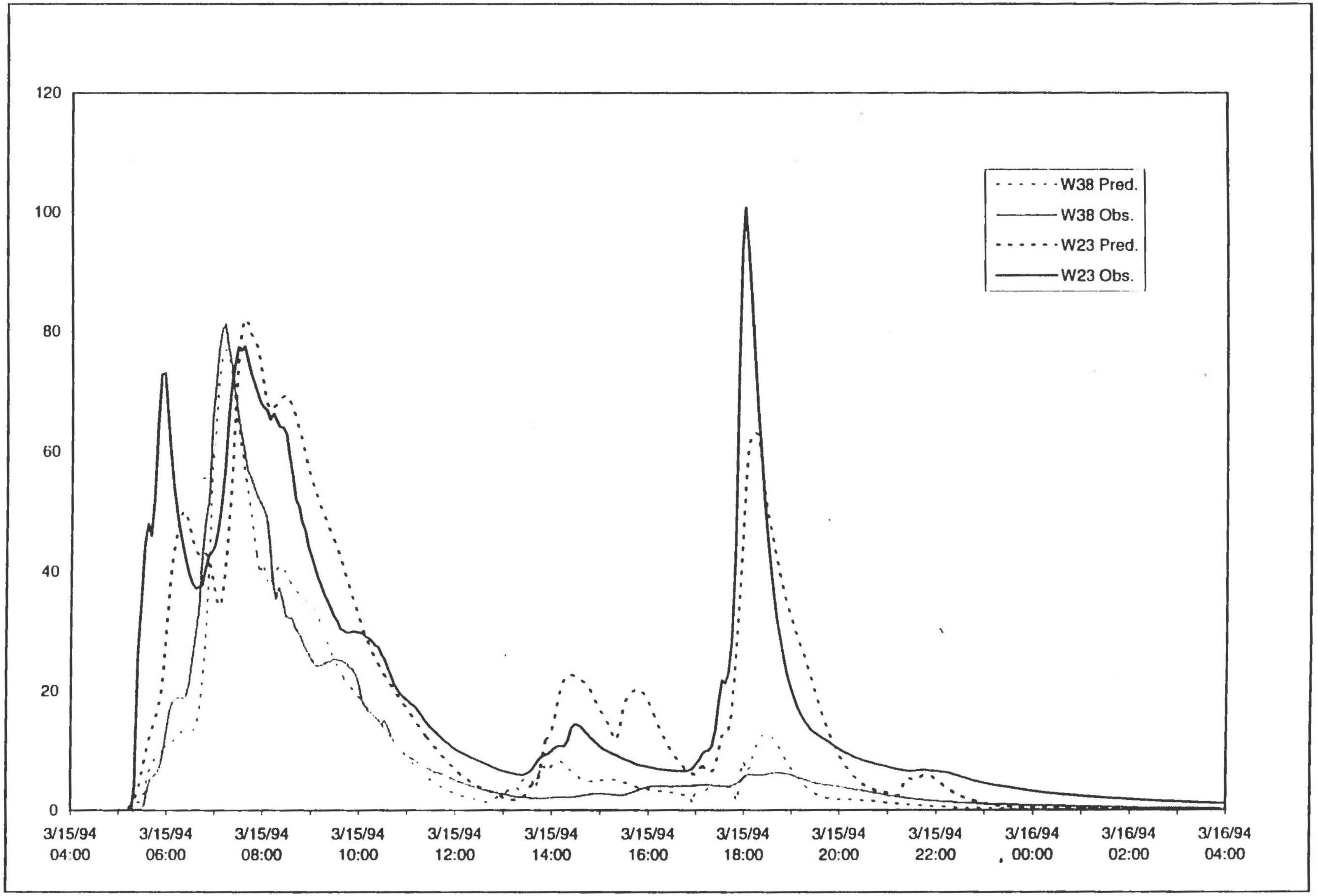
Appendix B
Observed and Predicted Hydographs



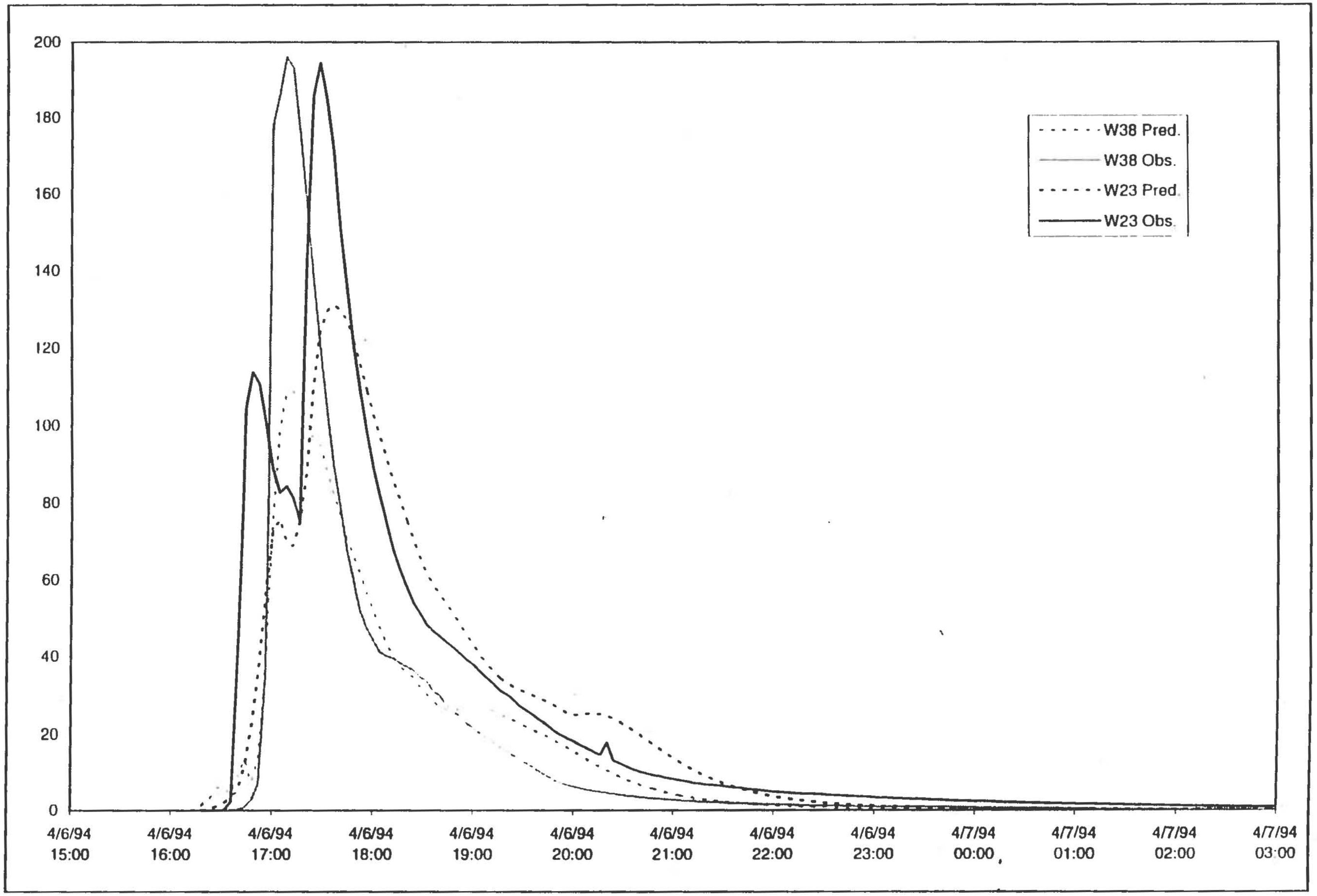
Appendix B
Observed and Predicted Hydographs



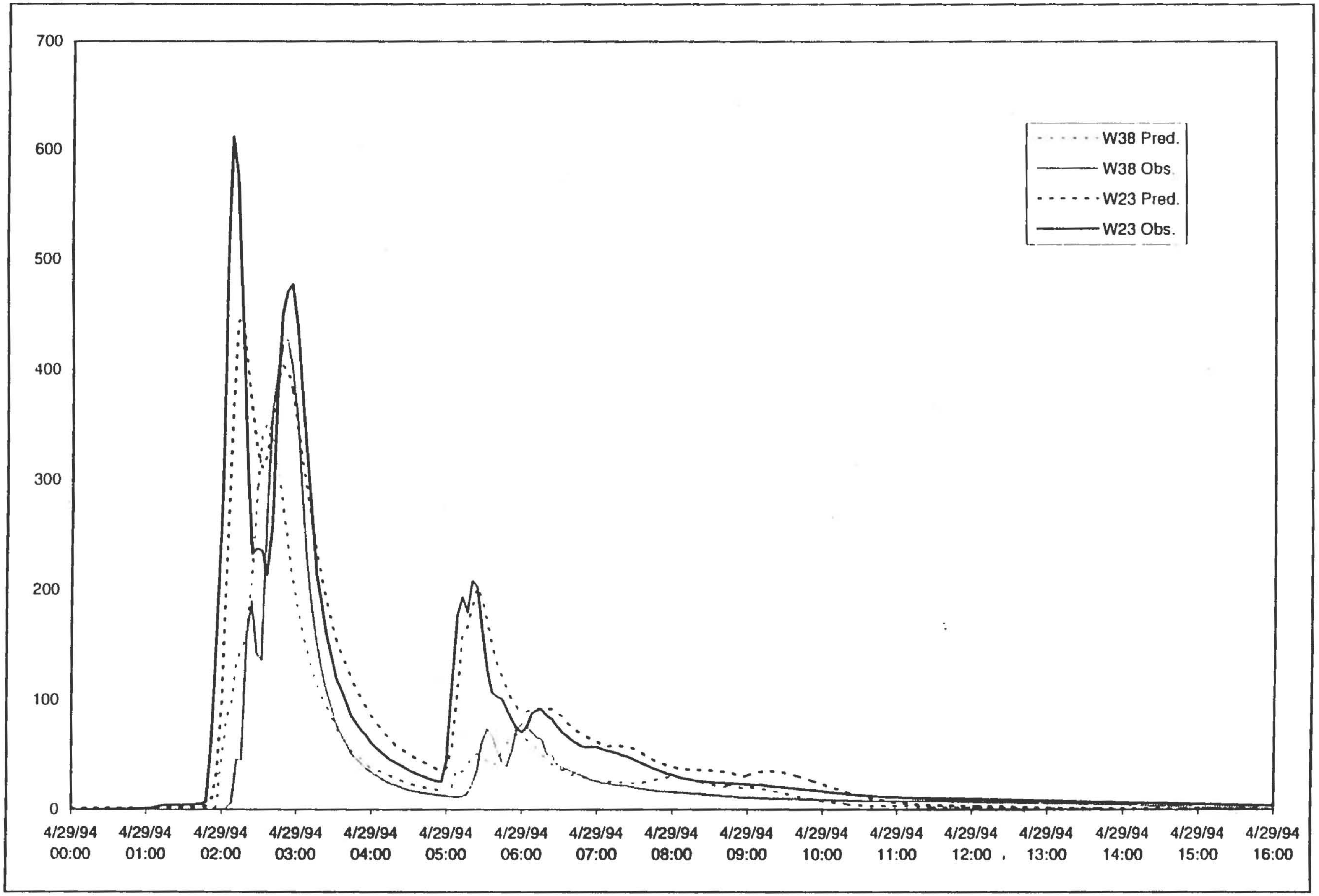
Appendix B
Observed and Predicted Hydographs



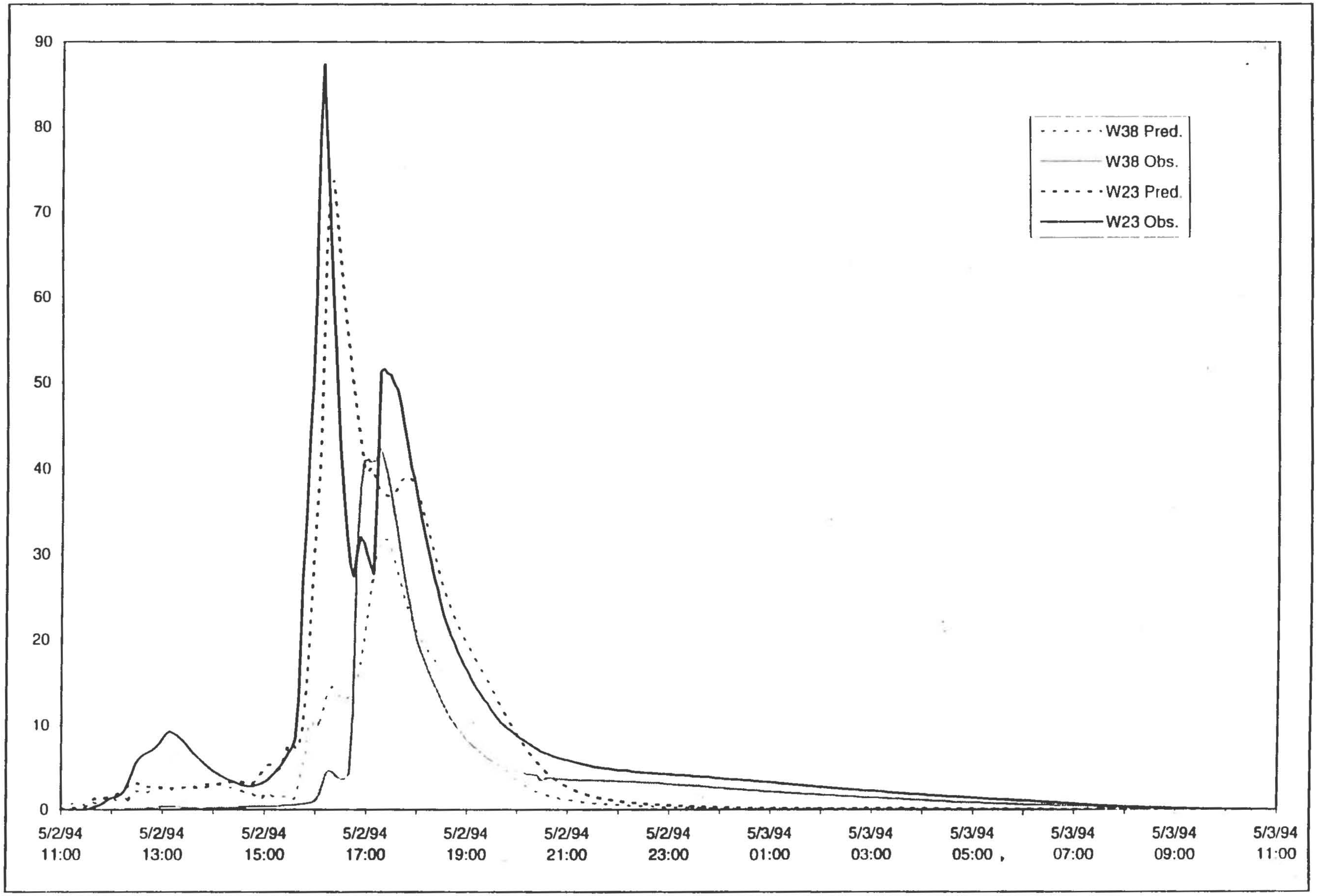
Appendix B
Observed and Predicted Hydographs



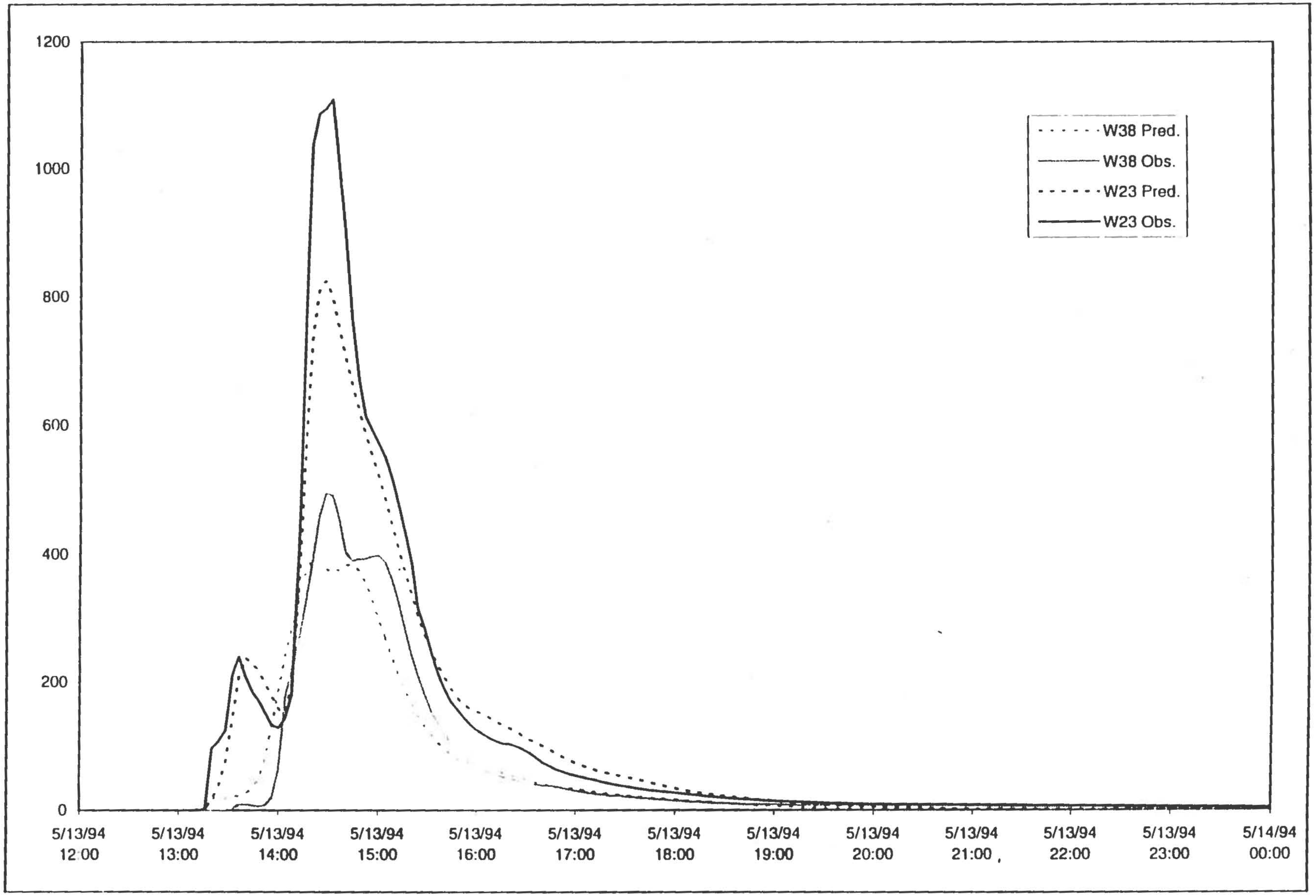
Appendix B
Observed and Predicted Hydographs



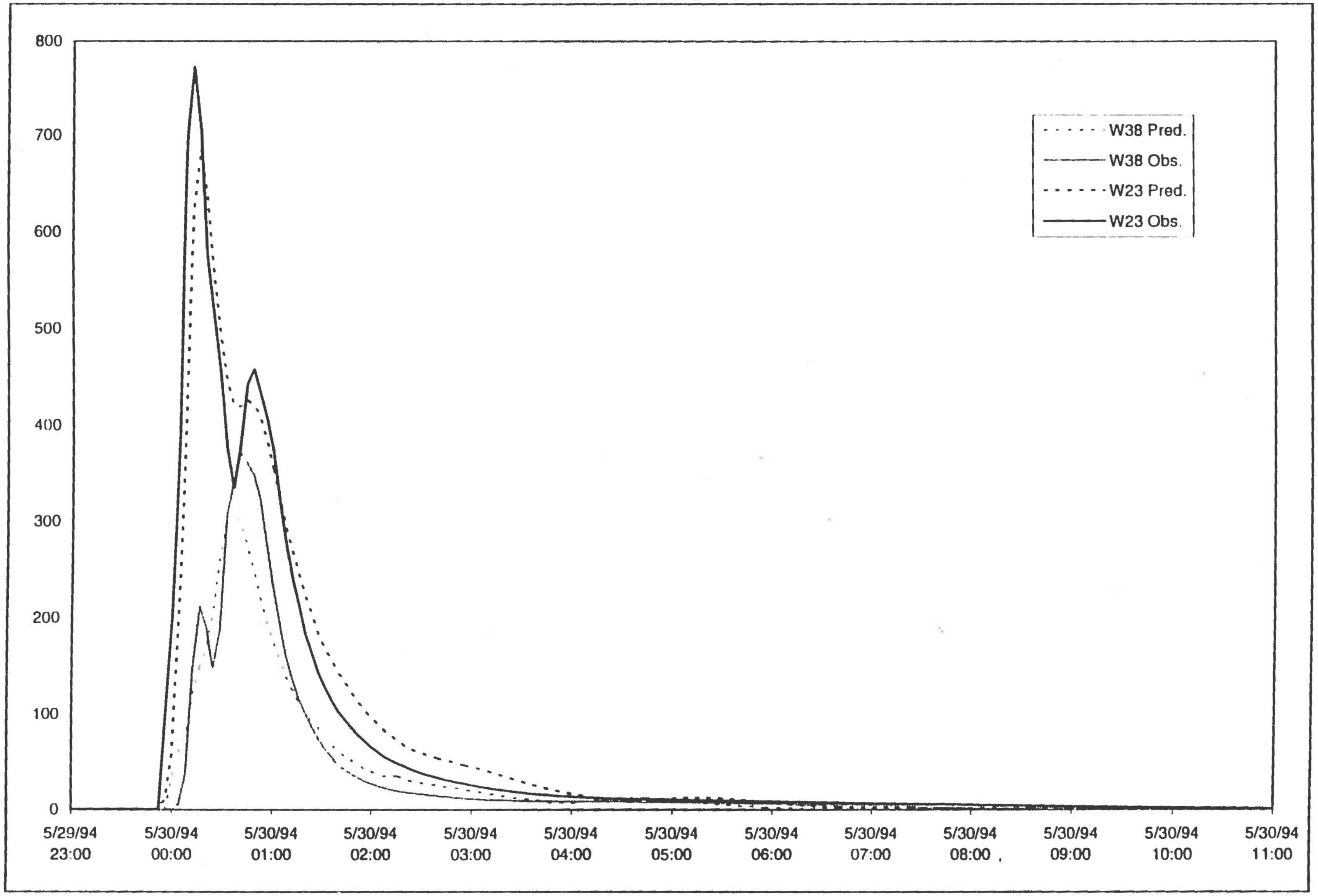
Appendix B
Observed and Predicted Hydrographs



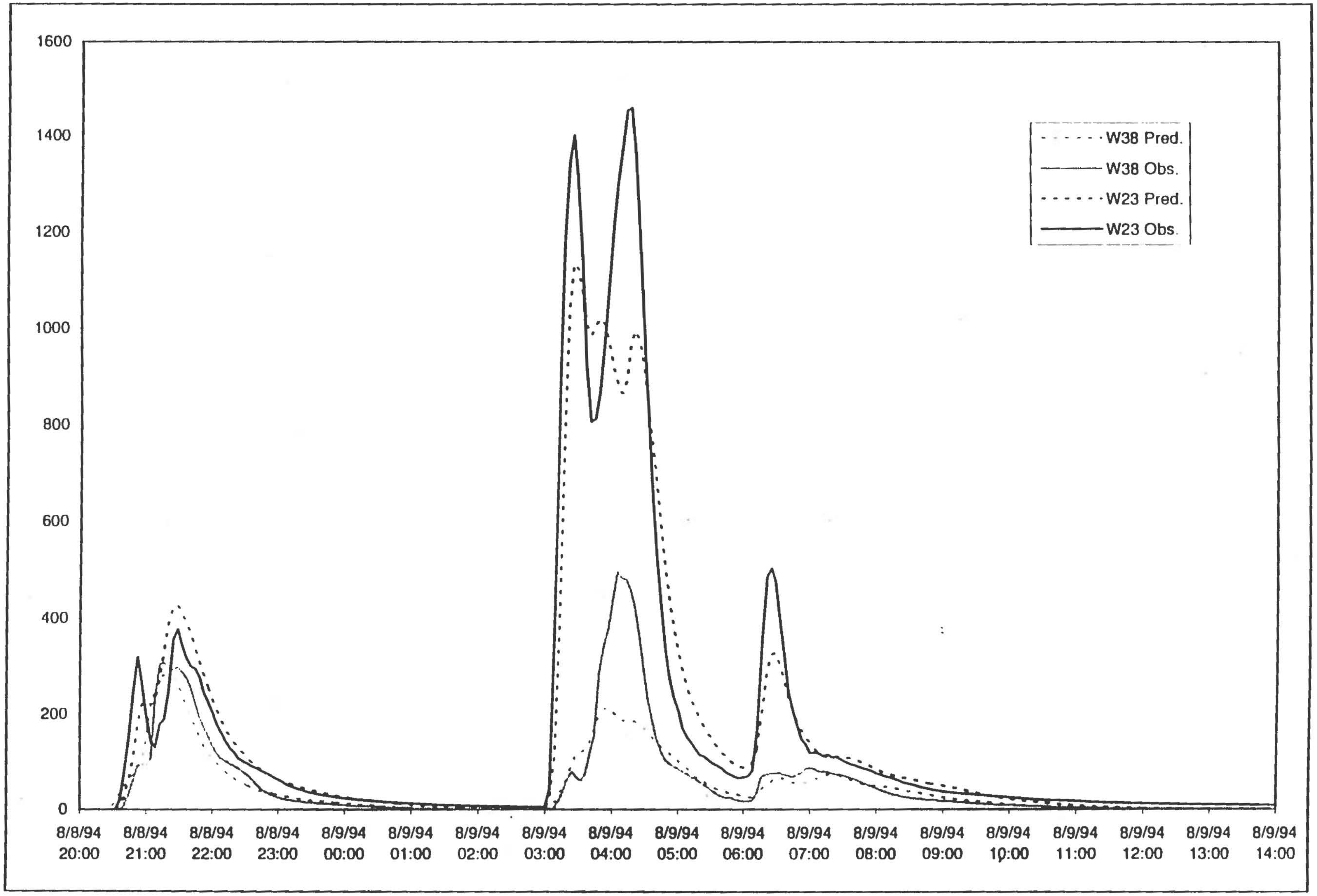
Appendix B
Observed and Predicted Hydographs



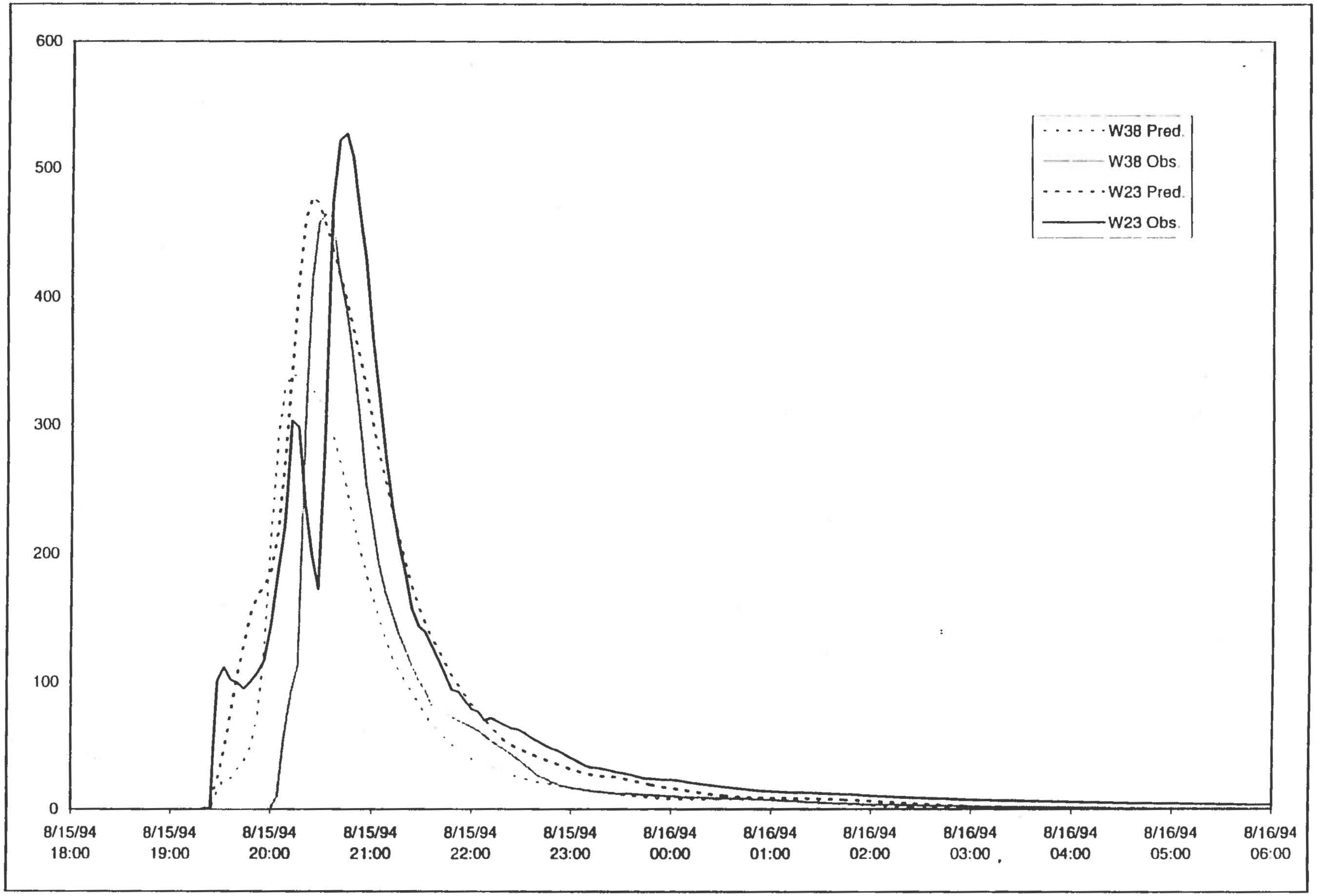
Appendix B
Observed and Predicted Hydrographs

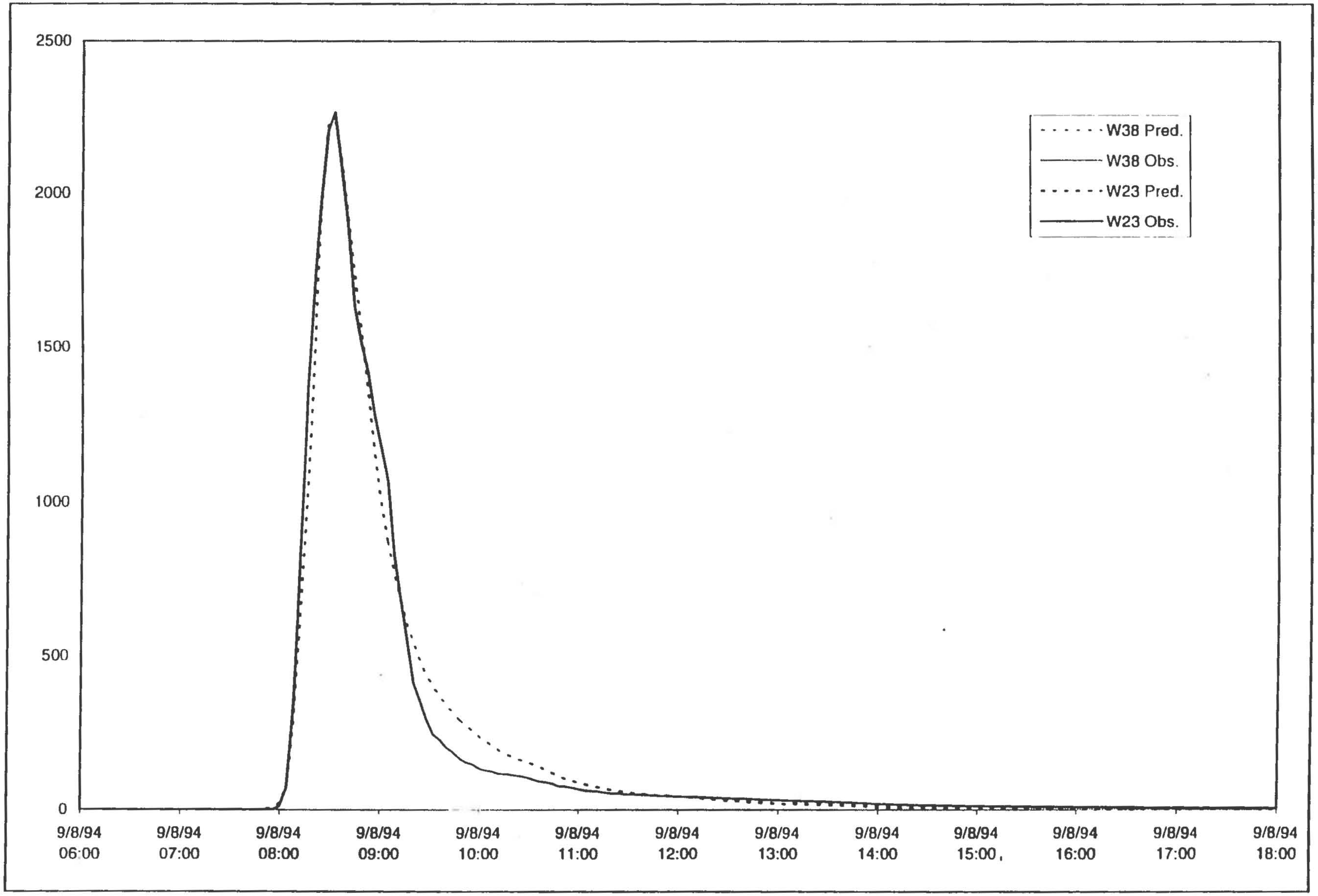


Appendix B
Observed and Predicted Hydographs

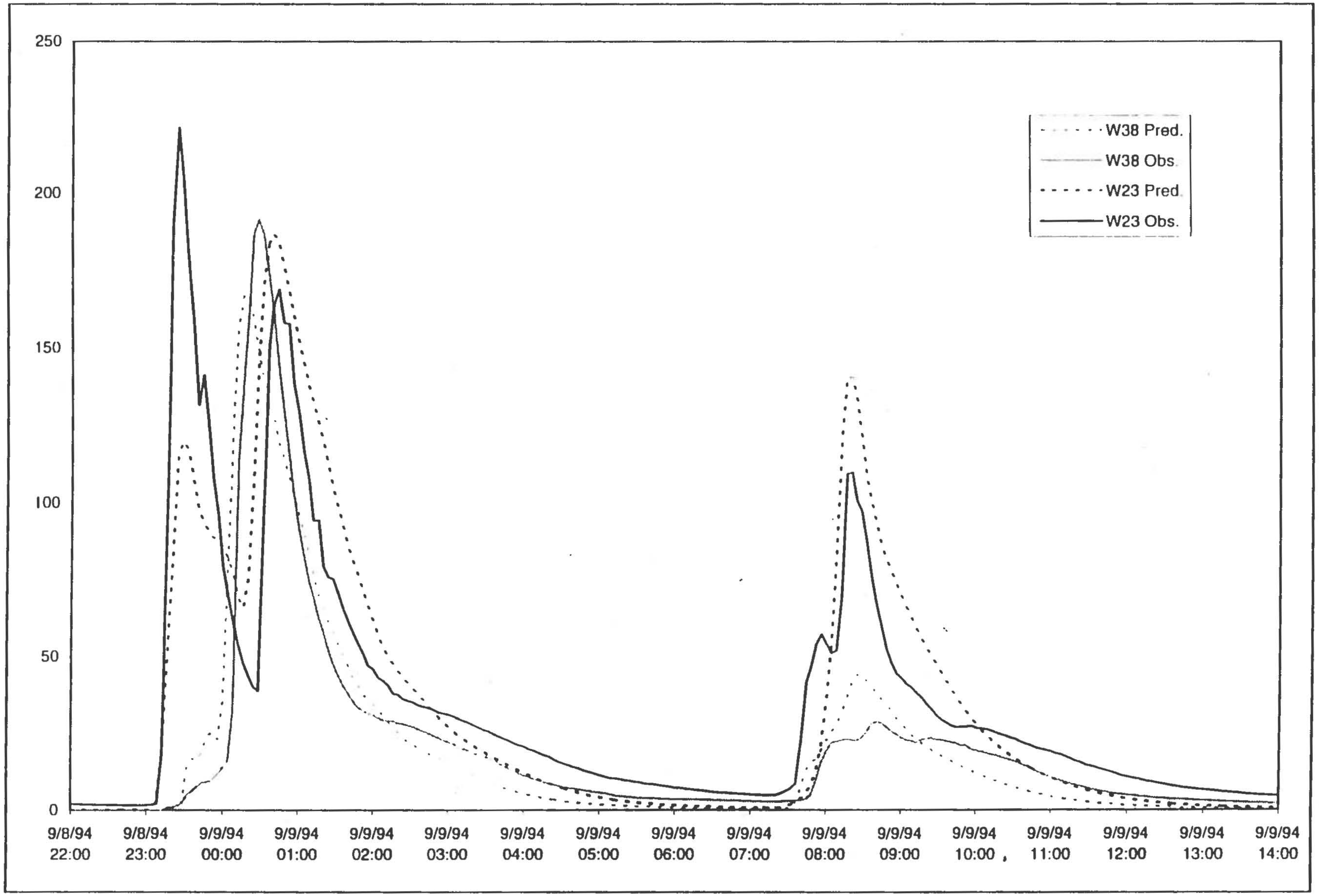


Appendix B
Observed and Predicted Hydographs

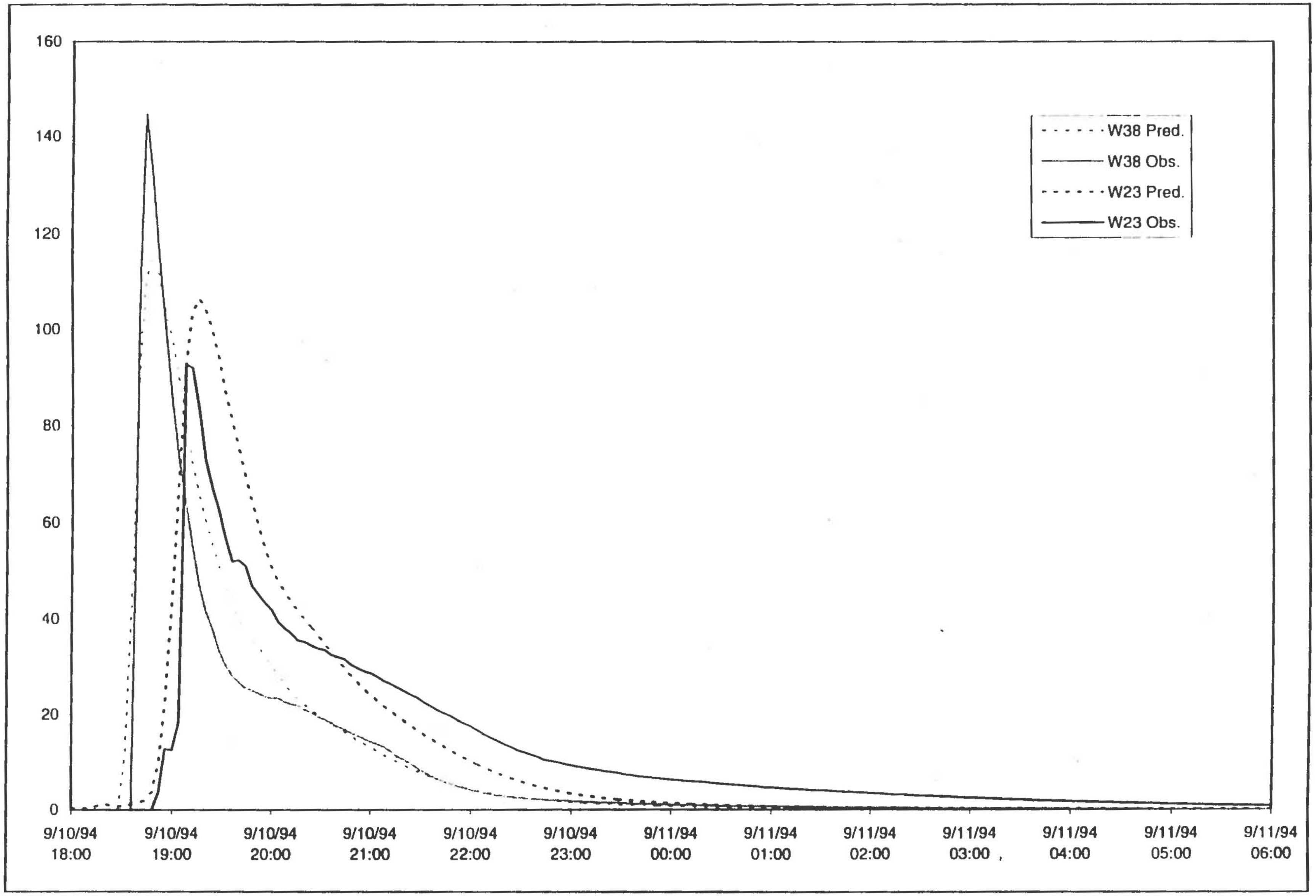



2500
2000
1500
1000
500
0
W38 Pred.
W38 Obs.
W23 Pred.
W23 Obs.
9/8/94 06:00
9/8/94 07:00
9/8/94 08:00
9/8/94 09:00
9/8/94 10:00
9/8/94 11:00
9/8/94 12:00
9/8/94 13:00
9/8/94 14:00
9/8/94 15:00
9/8/94 16:00
9/8/94 17:00
9/8/94 18:00

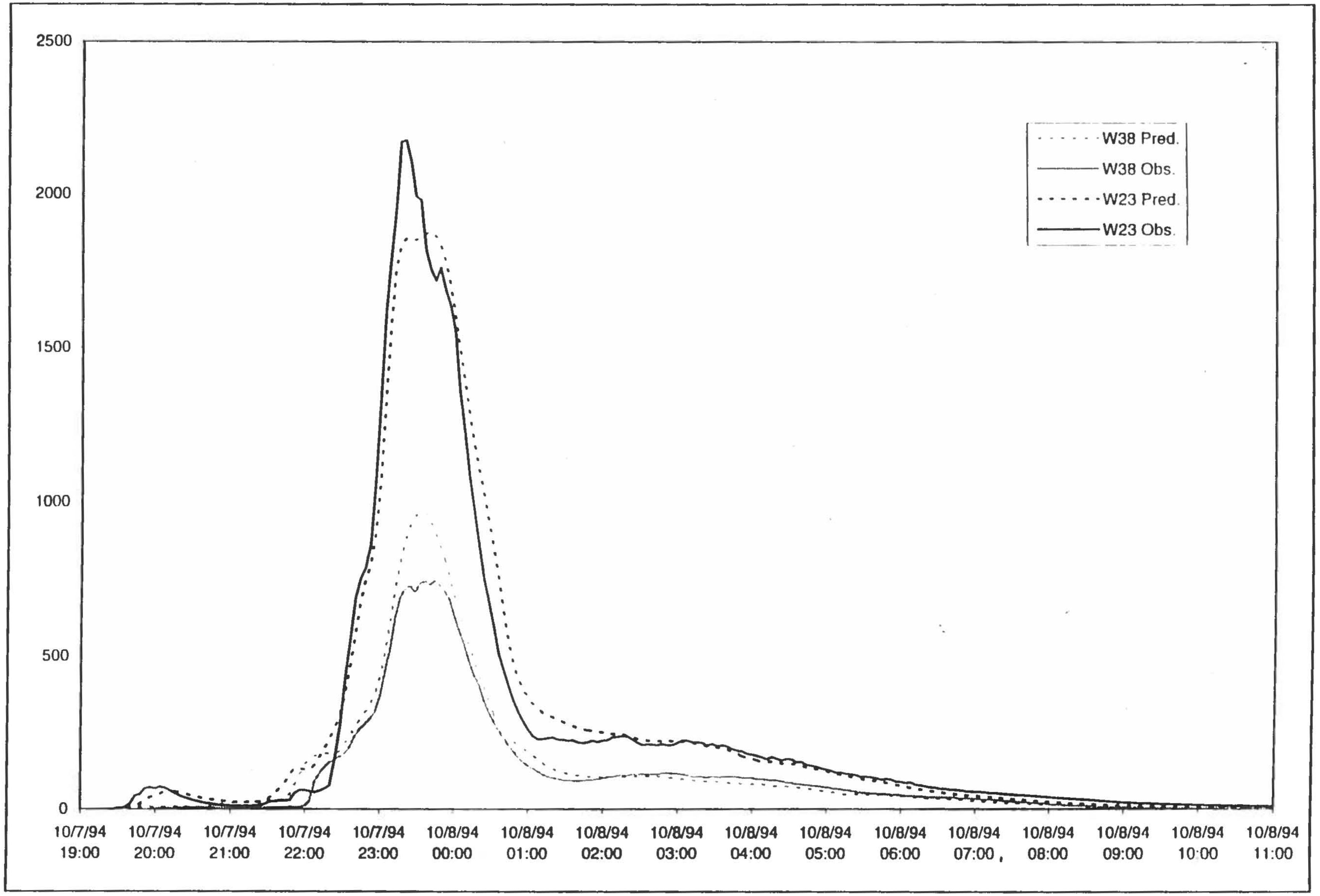
Appendix B
Observed and Predicted Hydographs



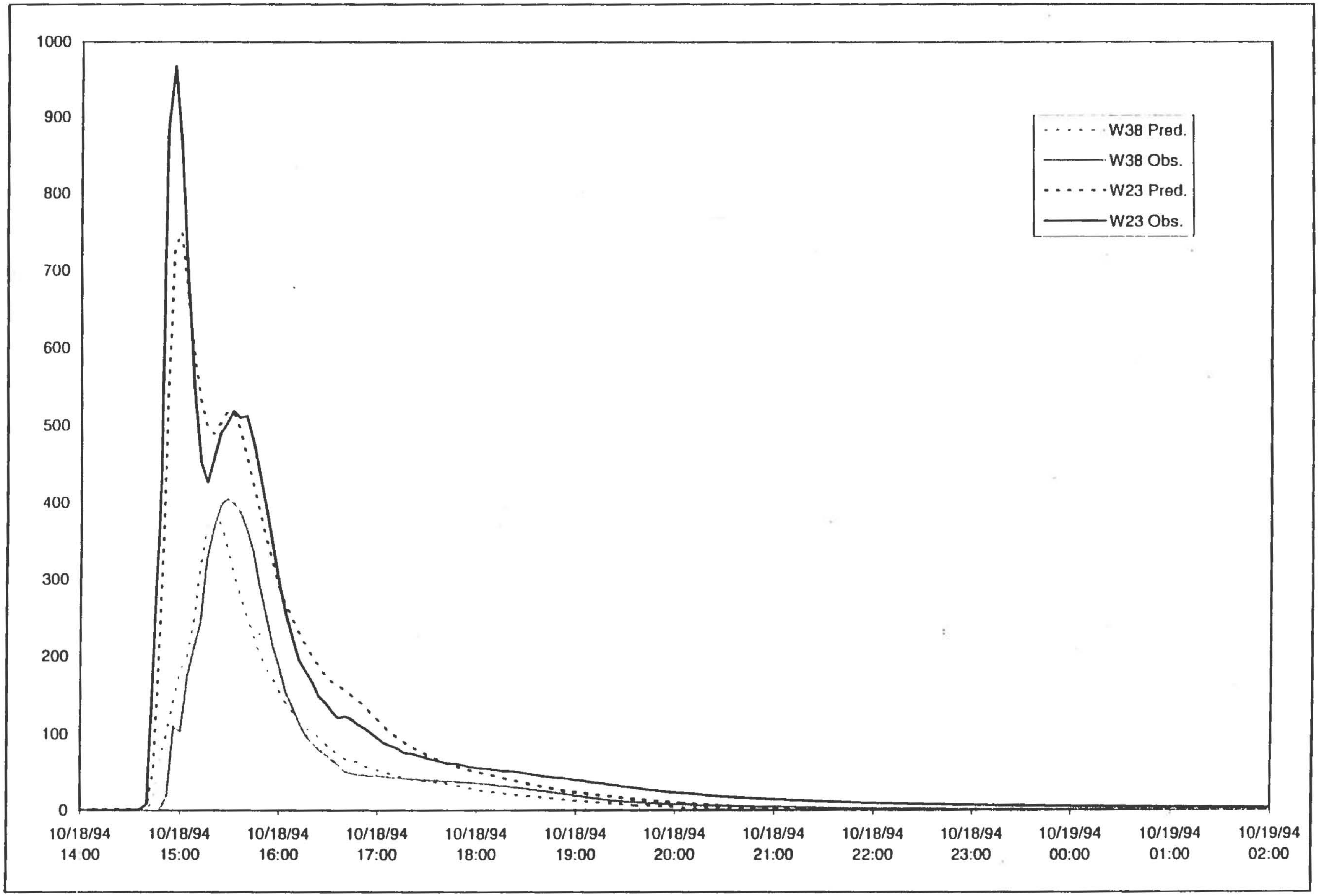
Appendix B
Observed and Predicted Hydrographs



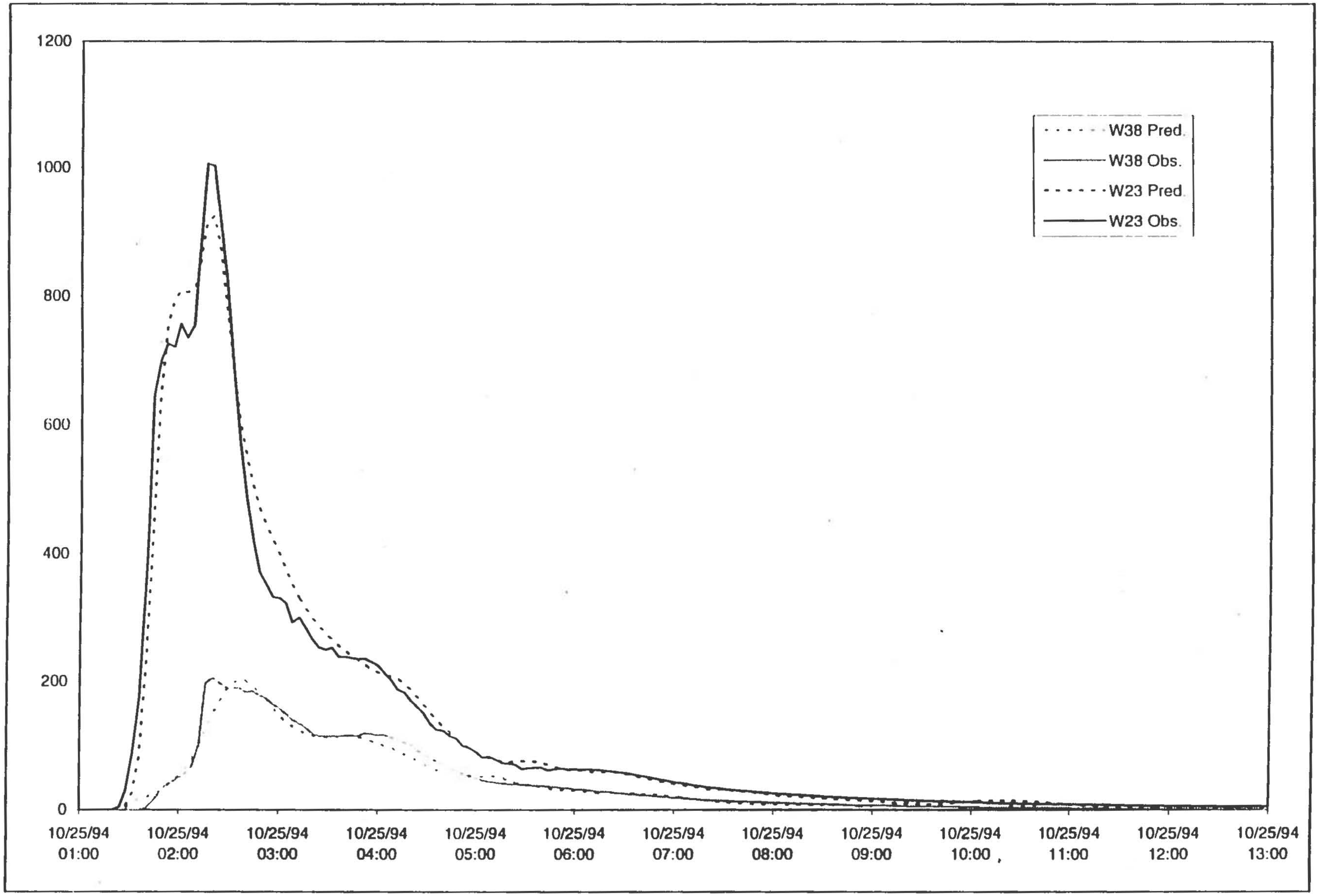
Appendix B
Observed and Predicted Hydographs

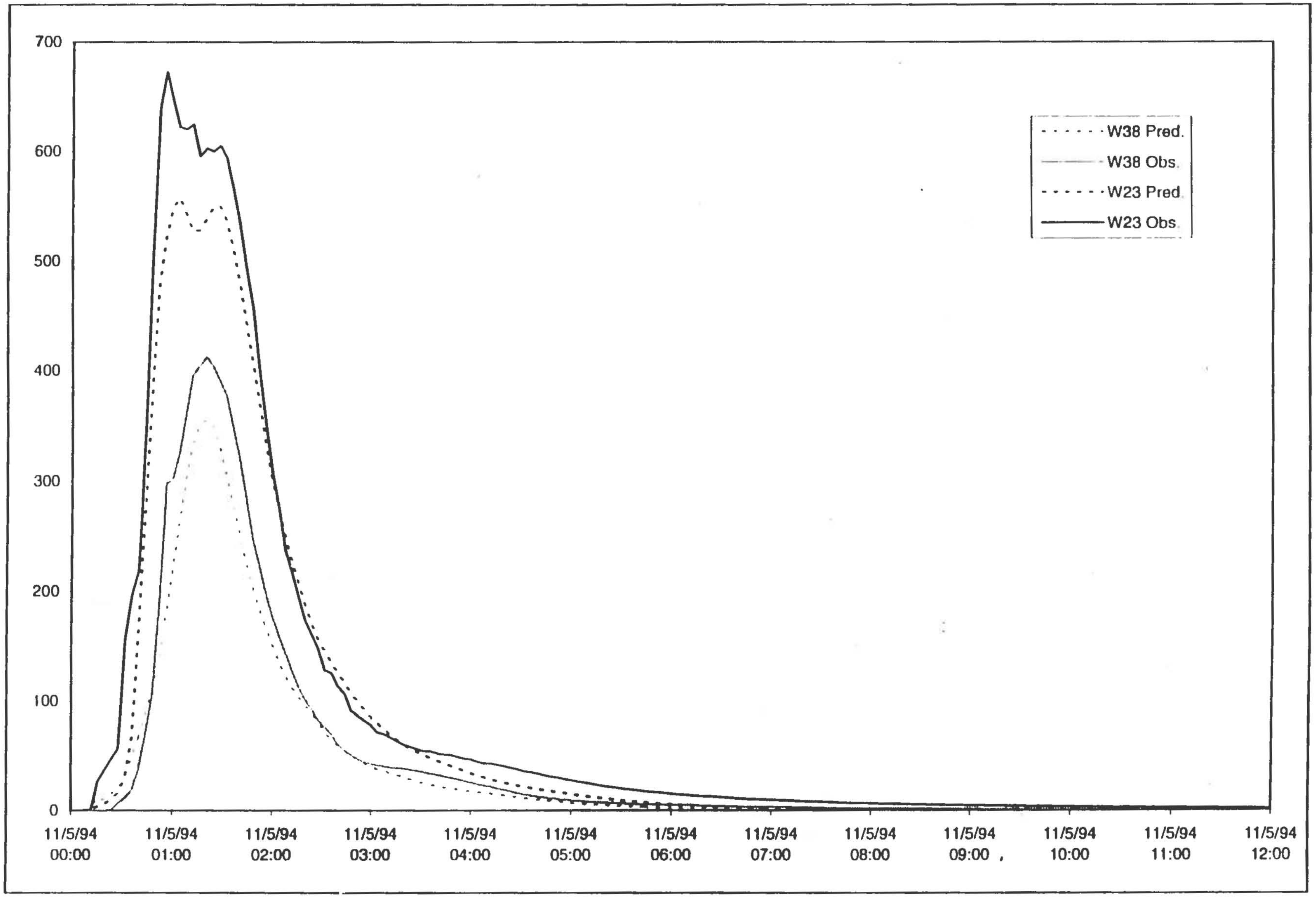


Appendix B
Observed and Predicted Hydrographs

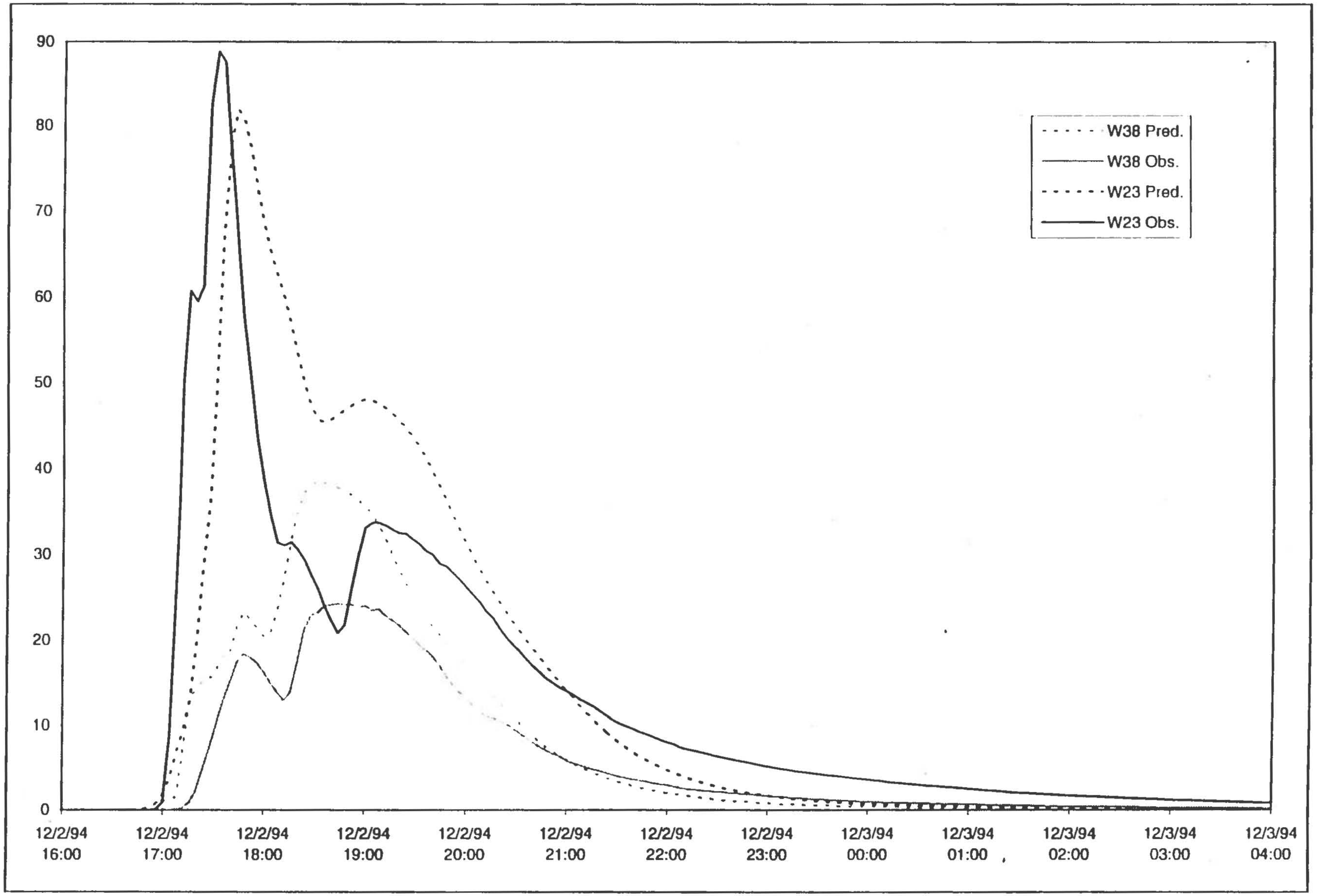


Appendix B
Observed and Predicted Hydographs

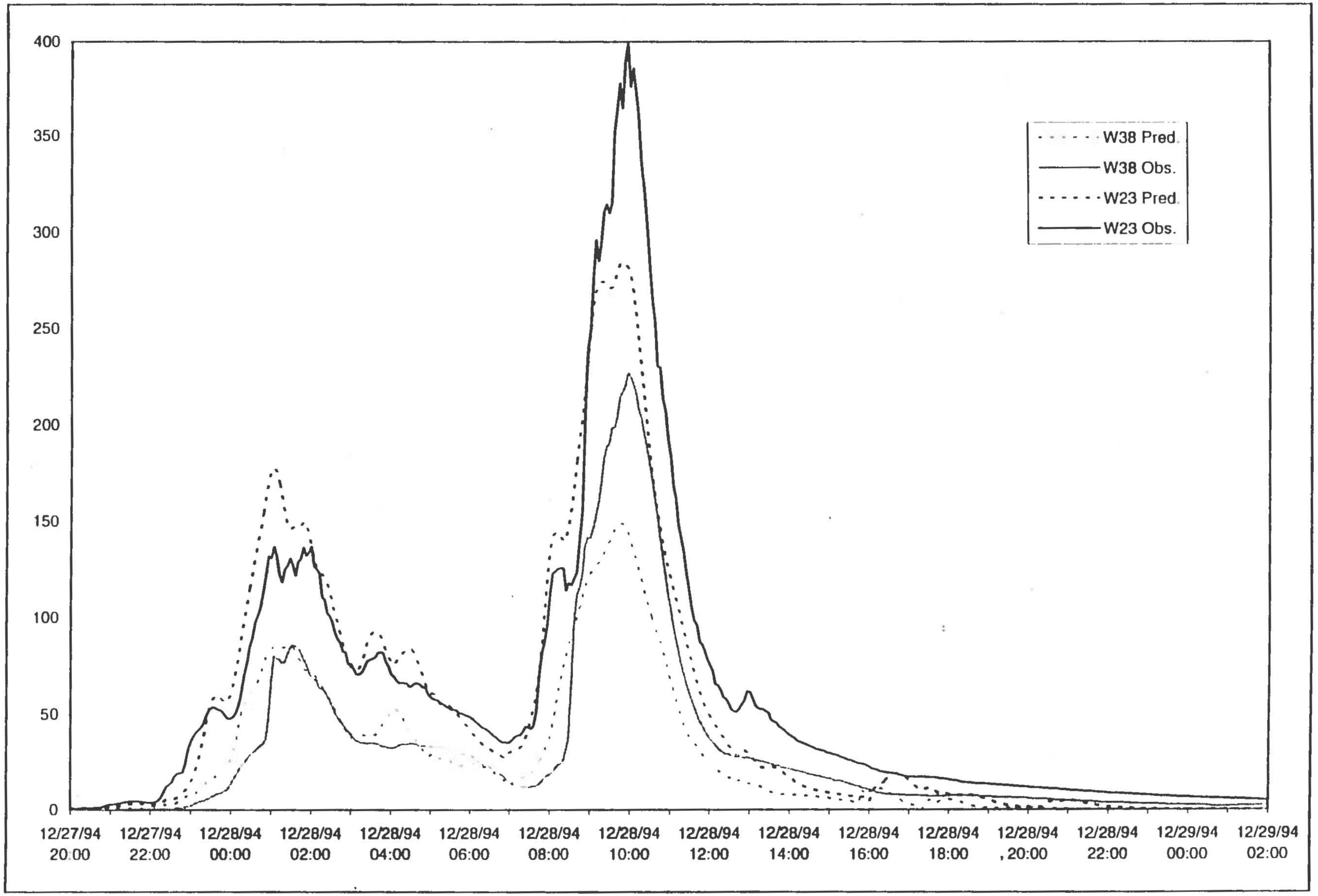


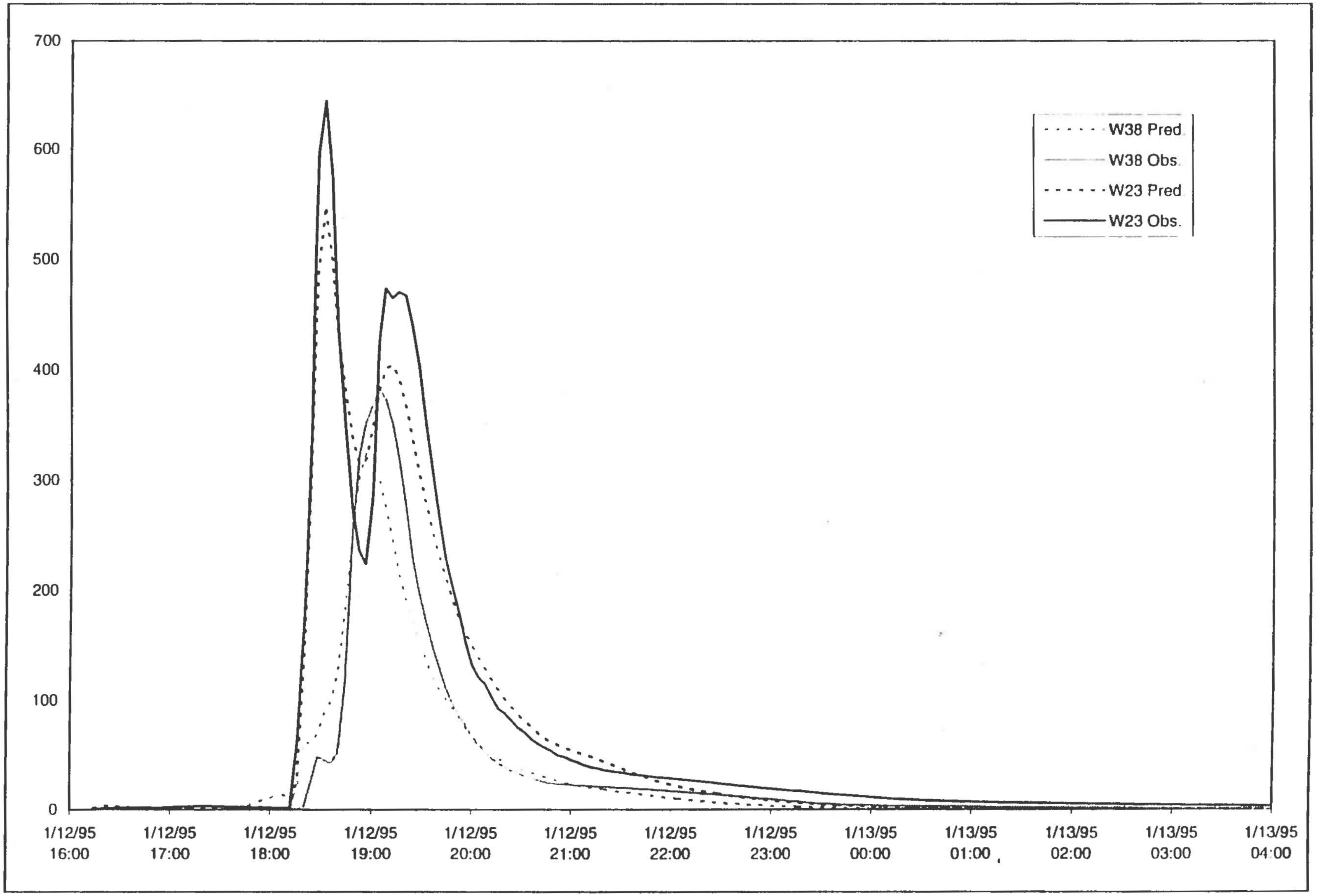

700
600
500
400
300
200
100
0
W38 Pred.
W38 Obs.
W23 Pred.
W23 Obs.
11/5/94 00:00
11/5/94 01:00
11/5/94 02:00
11/5/94 03:00
11/5/94 04:00
11/5/94 05:00
11/5/94 06:00
11/5/94 07:00
11/5/94 08:00
11/5/94 09:00
11/5/94 10:00
11/5/94 11:00
11/5/94 12:00

Appendix B
Observed and Predicted Hydographs

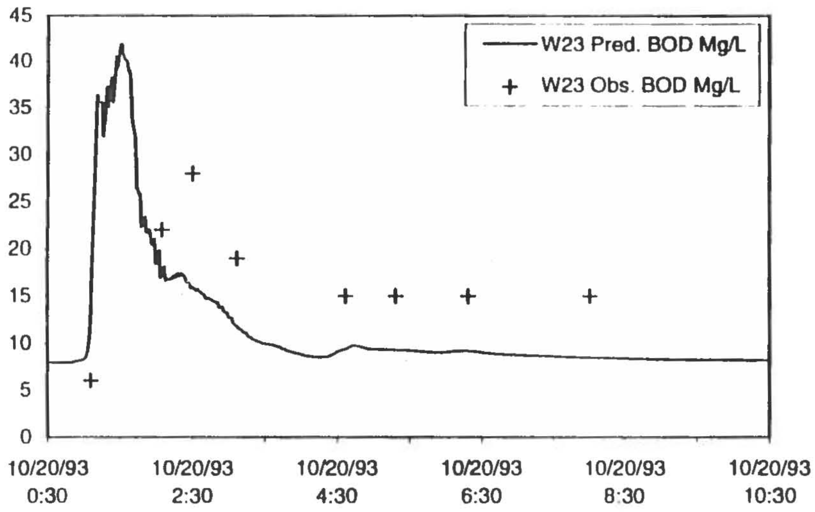


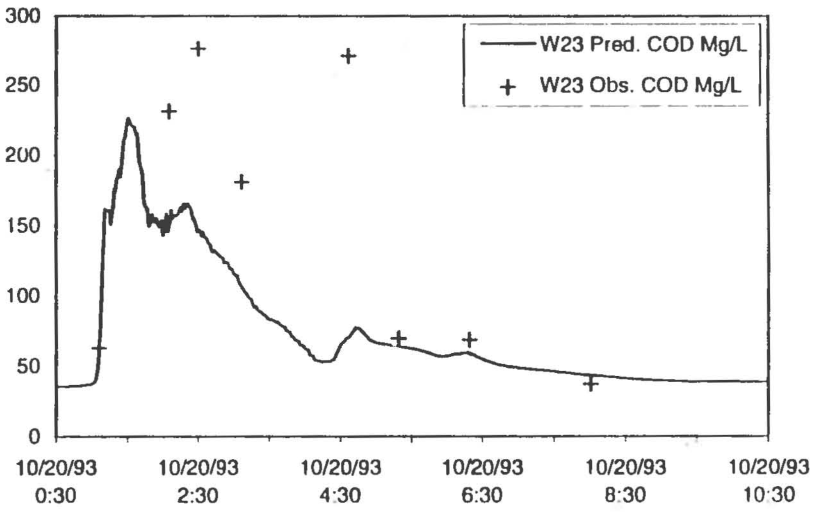
Appendix B
Observed and Predicted Hydographs

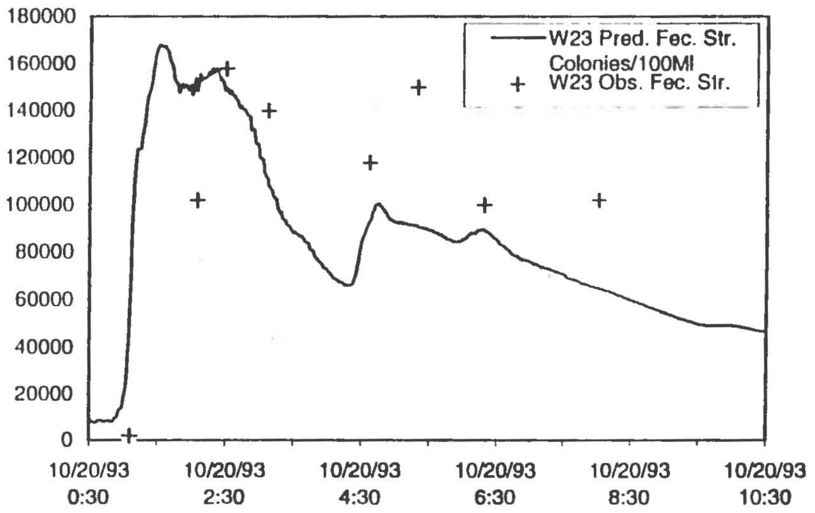


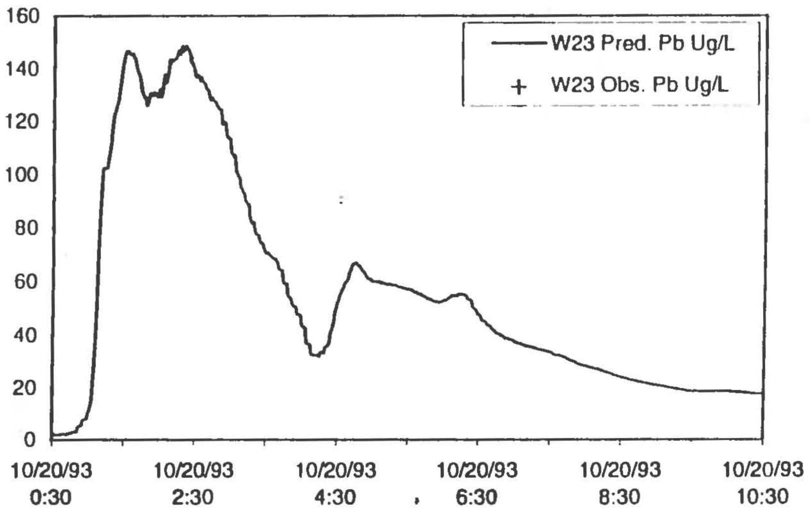

700
600
500
400
300
200
100
0
W38 Pred.
W38 Obs.
W23 Pred.
W23 Obs.
1/12/95 16:00
1/12/95 17:00
1/12/95 18:00
1/12/95 19:00
1/12/95 20:00
1/12/95 21:00
1/12/95 22:00
1/12/95 23:00
1/13/95 00:00
1/13/95 01:00
1/13/95 02:00
1/13/95 03:00
1/13/95 04:00

Appendix C
Observed and Predicted Pollutographs

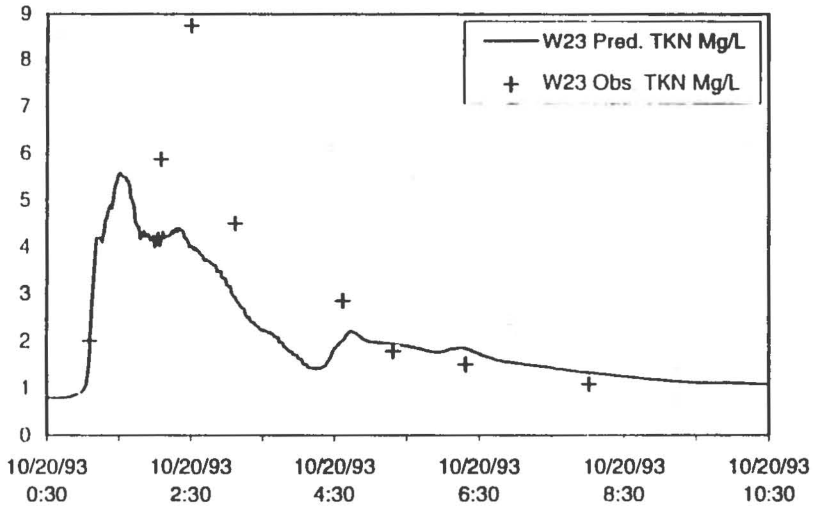


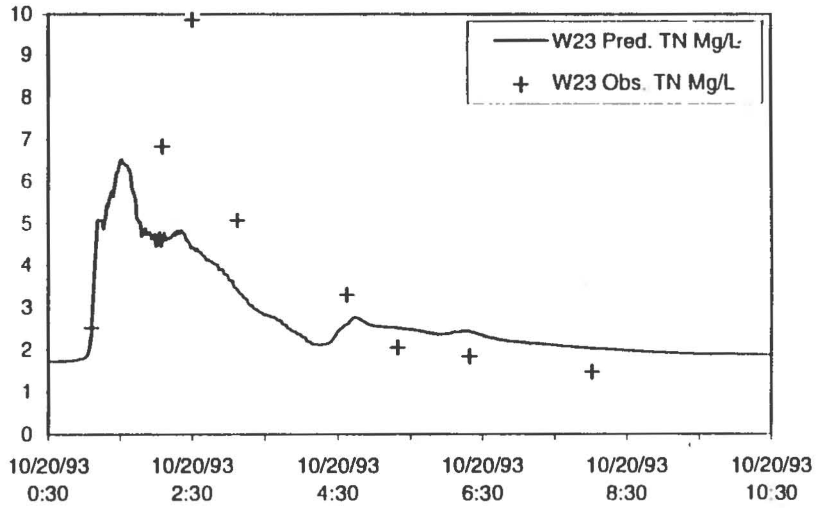


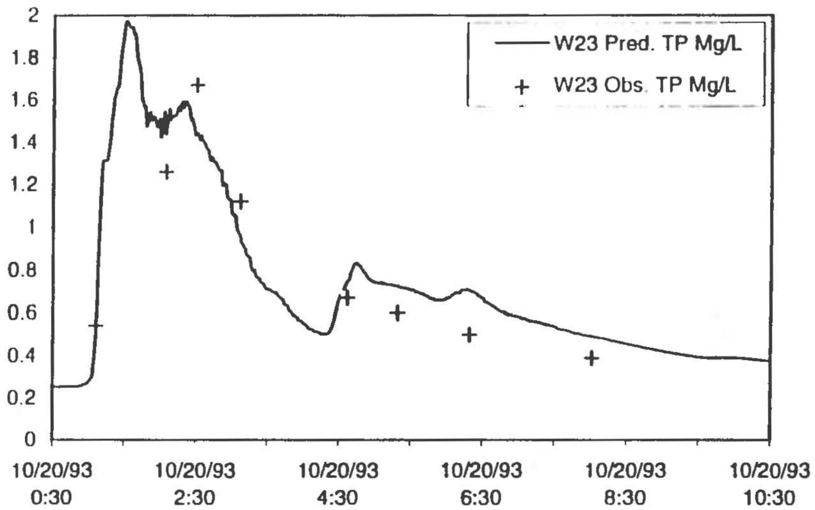


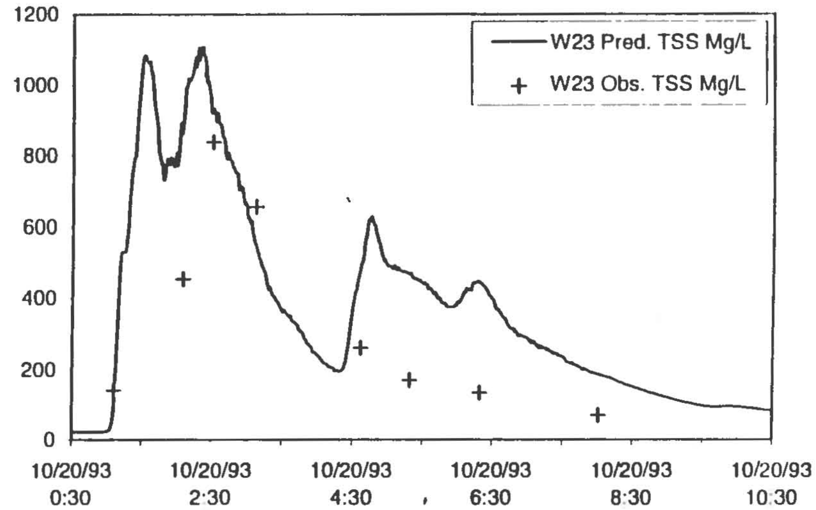


Appendix C
Observed and Predicted Pollutographs

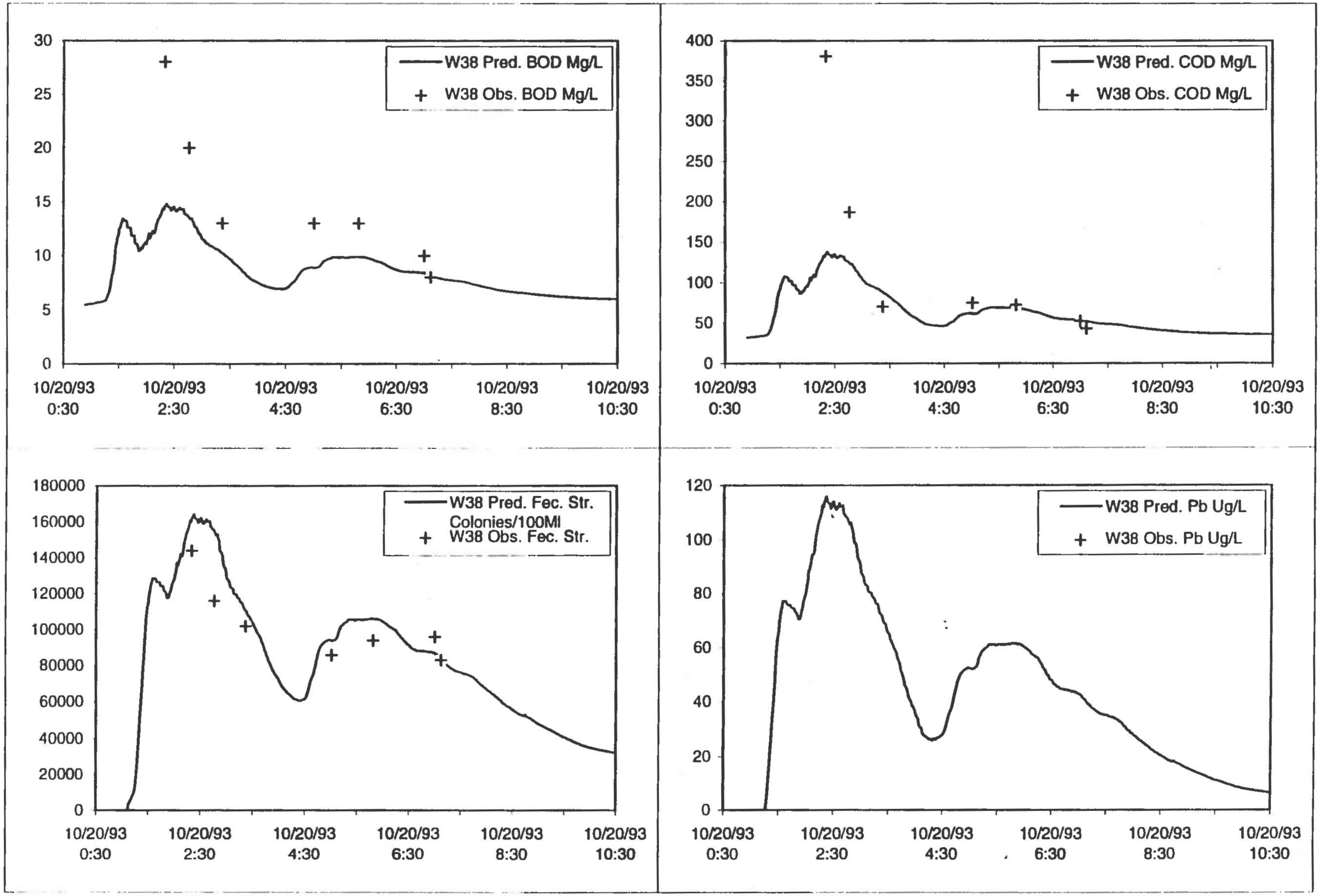




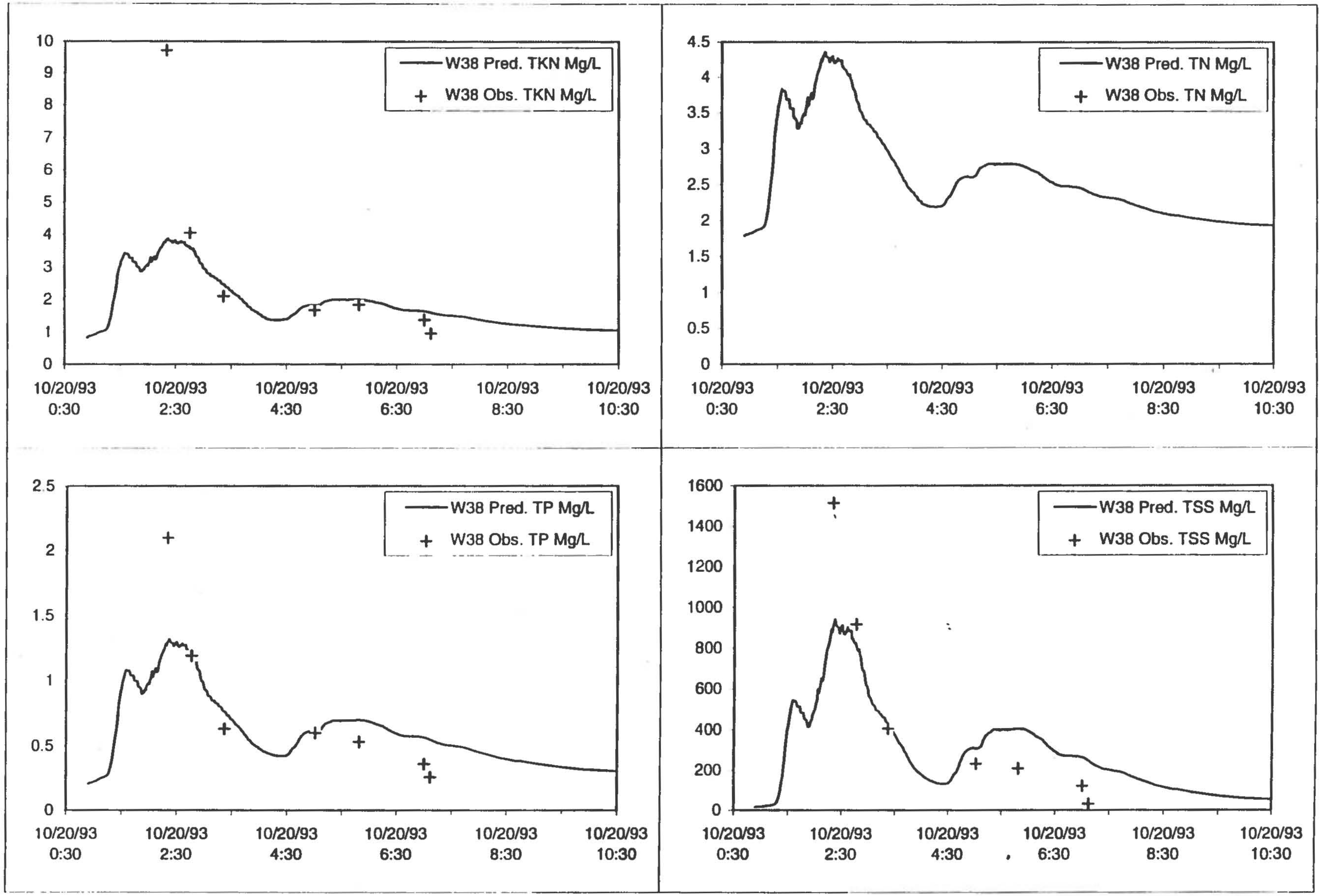




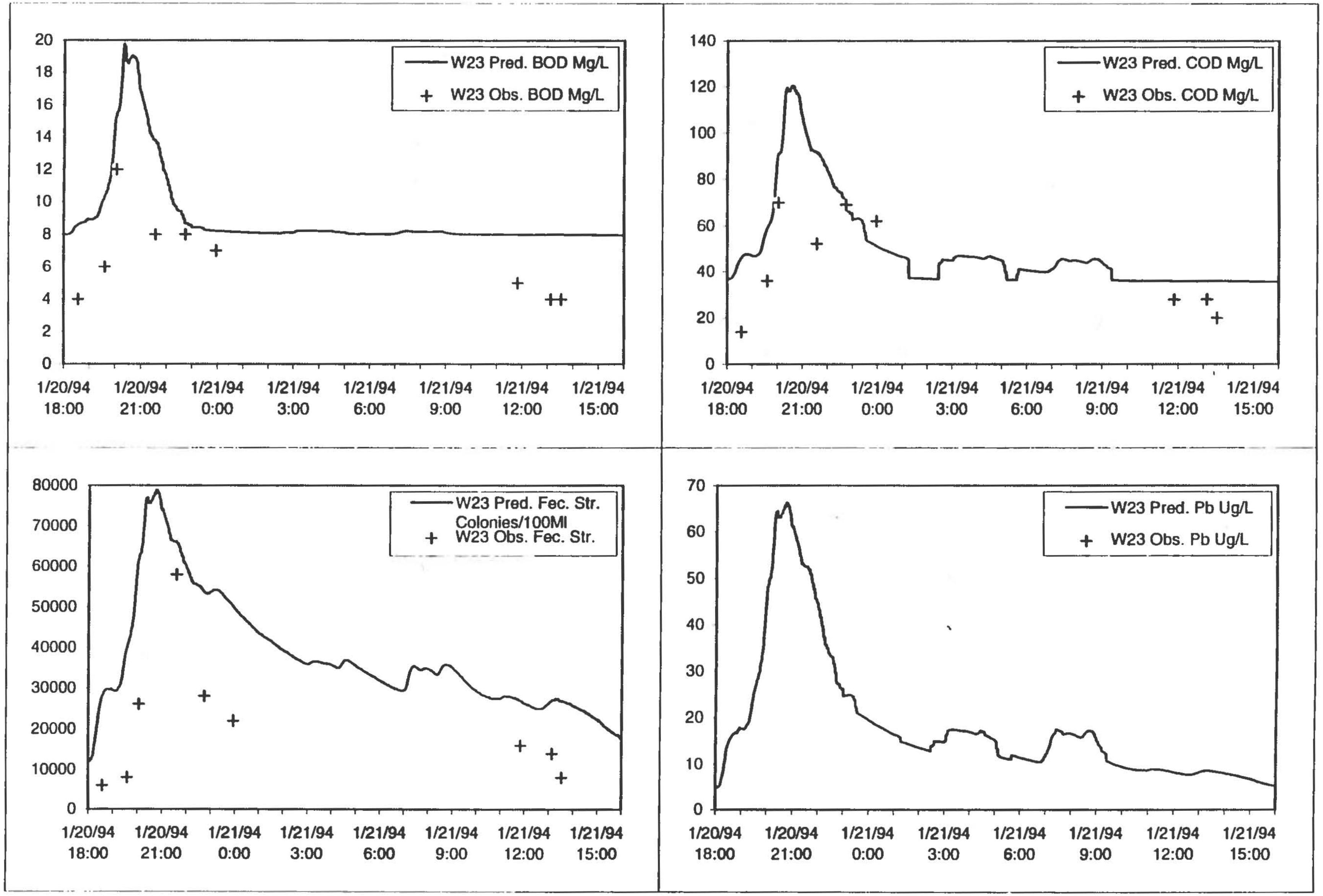
Appendix C
Observed and Predicted Pollutographs



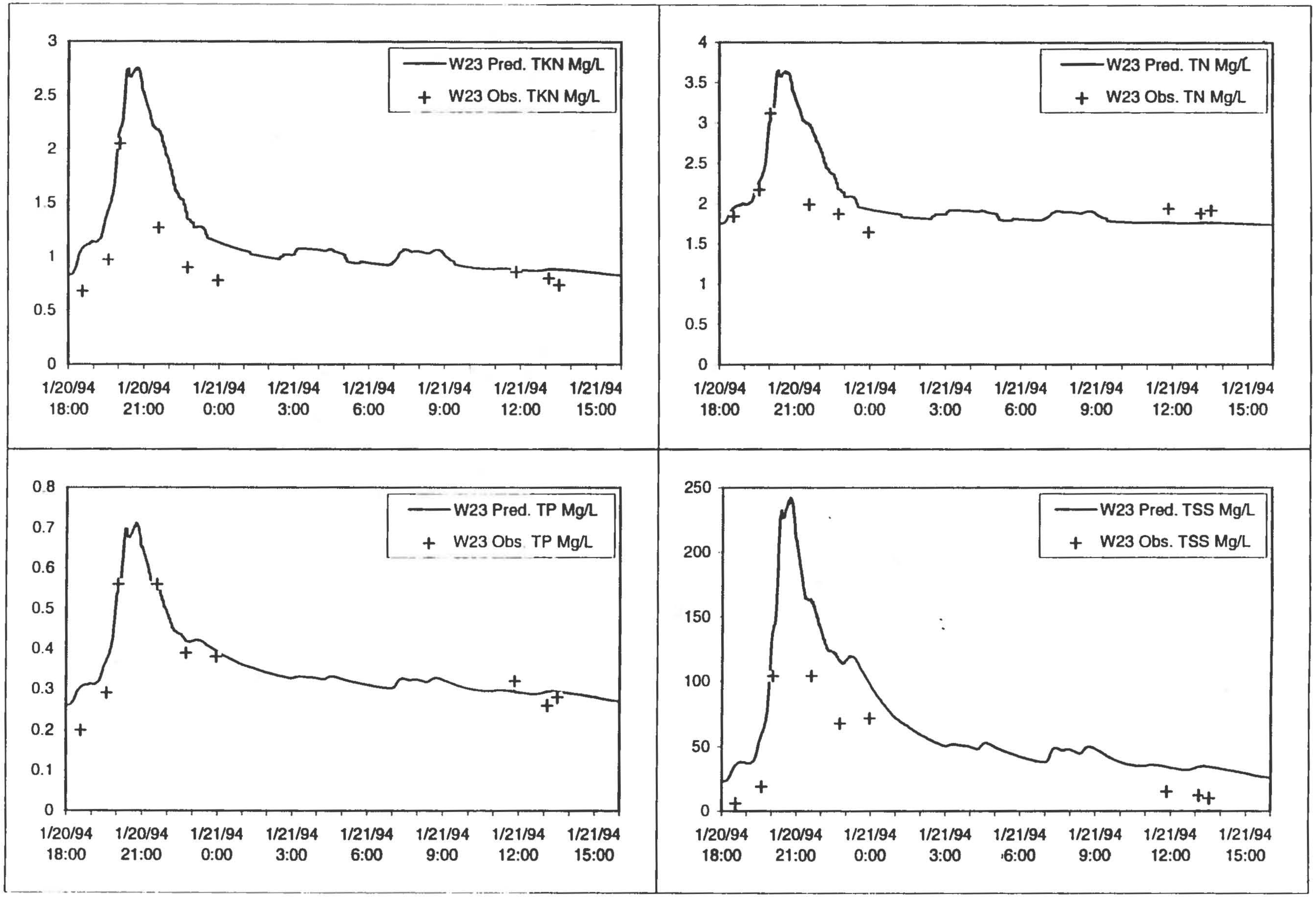
Appendix C
Observed and Predicted Pollutographs



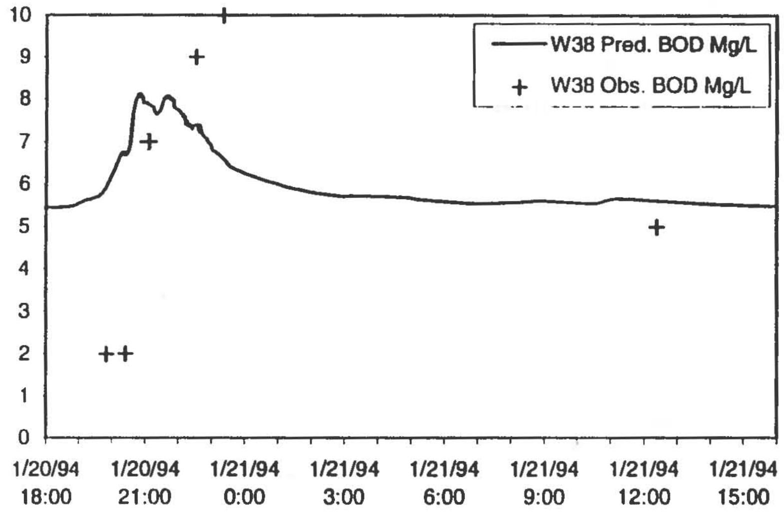
Appendix C
Observed and Predicted Pollutographs

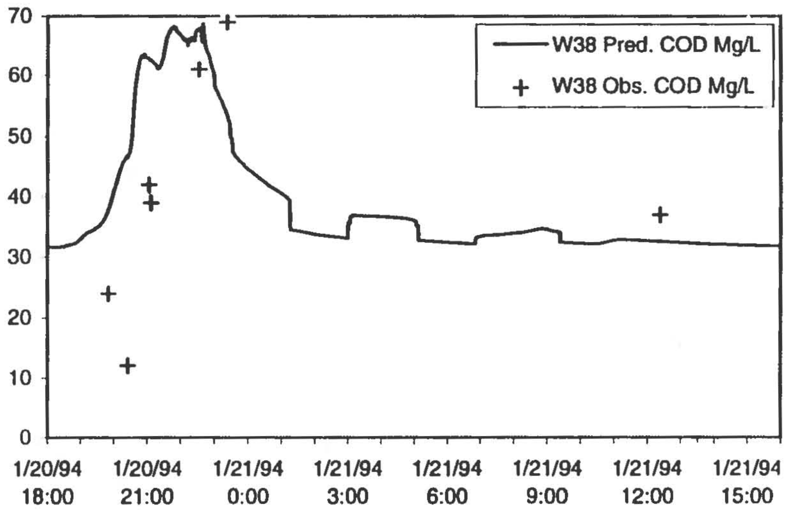


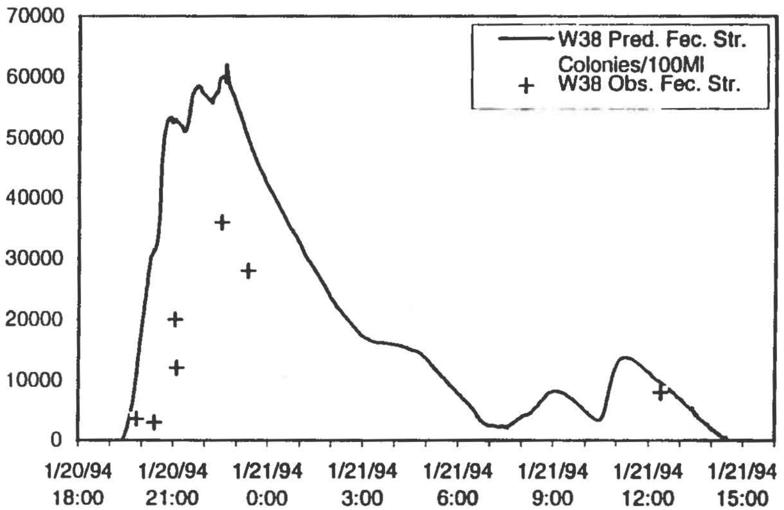
Appendix C
Observed and Predicted Pollutographs

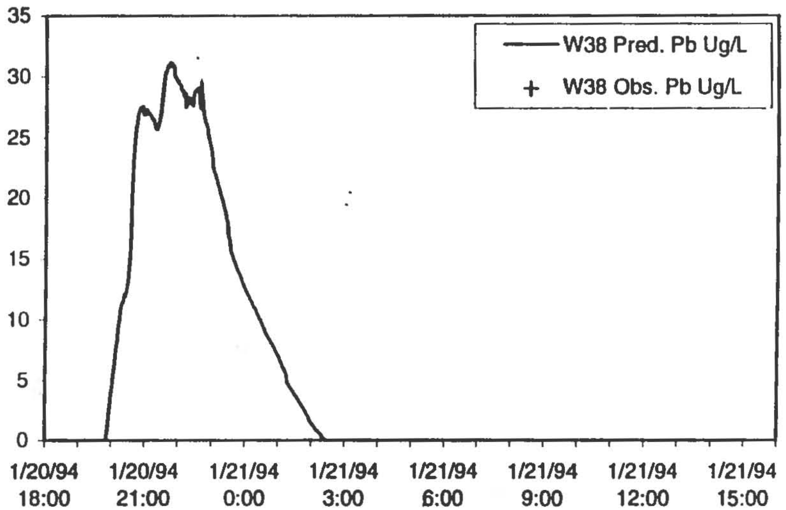


Appendix C
Observed and Predicted Pollutographs

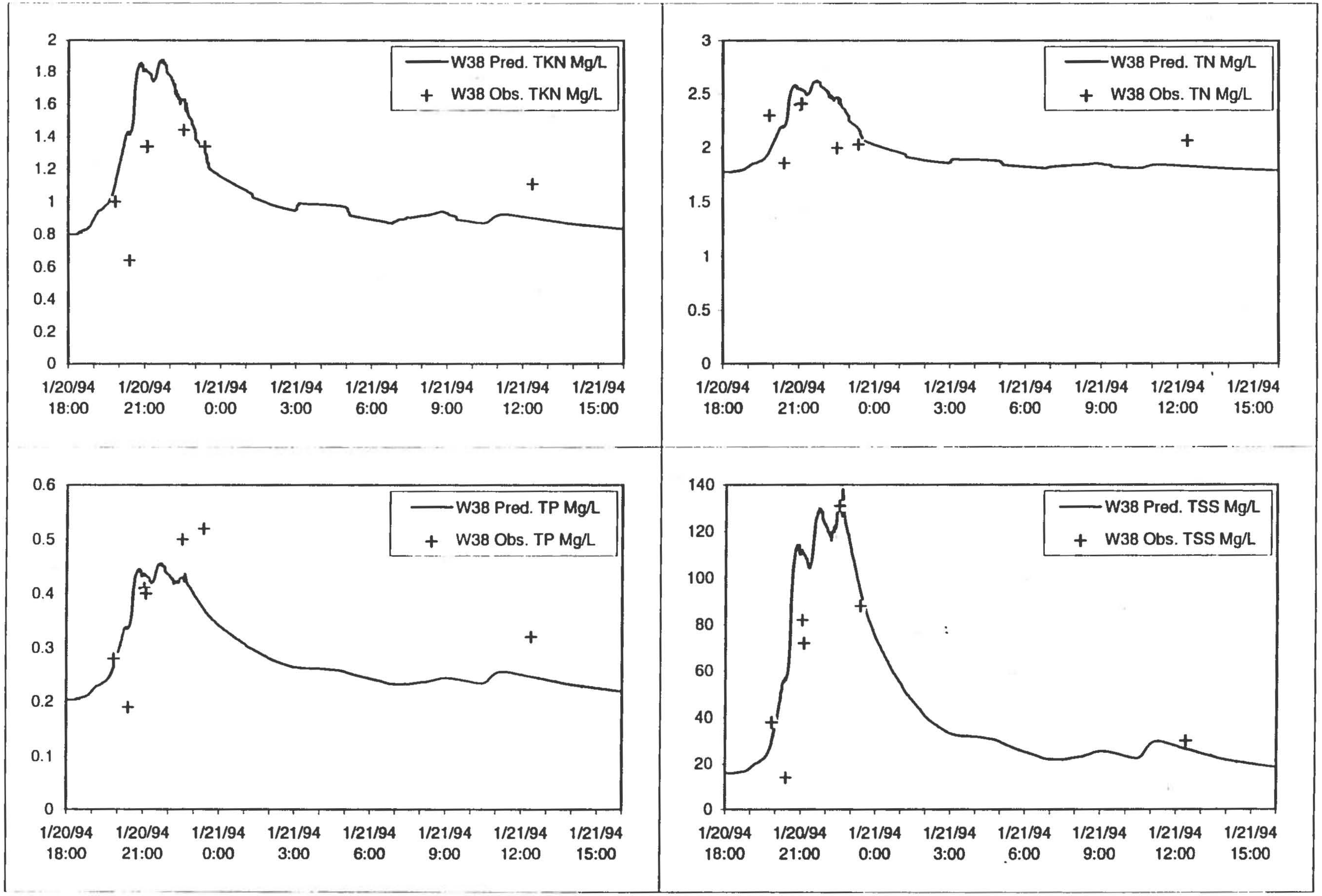




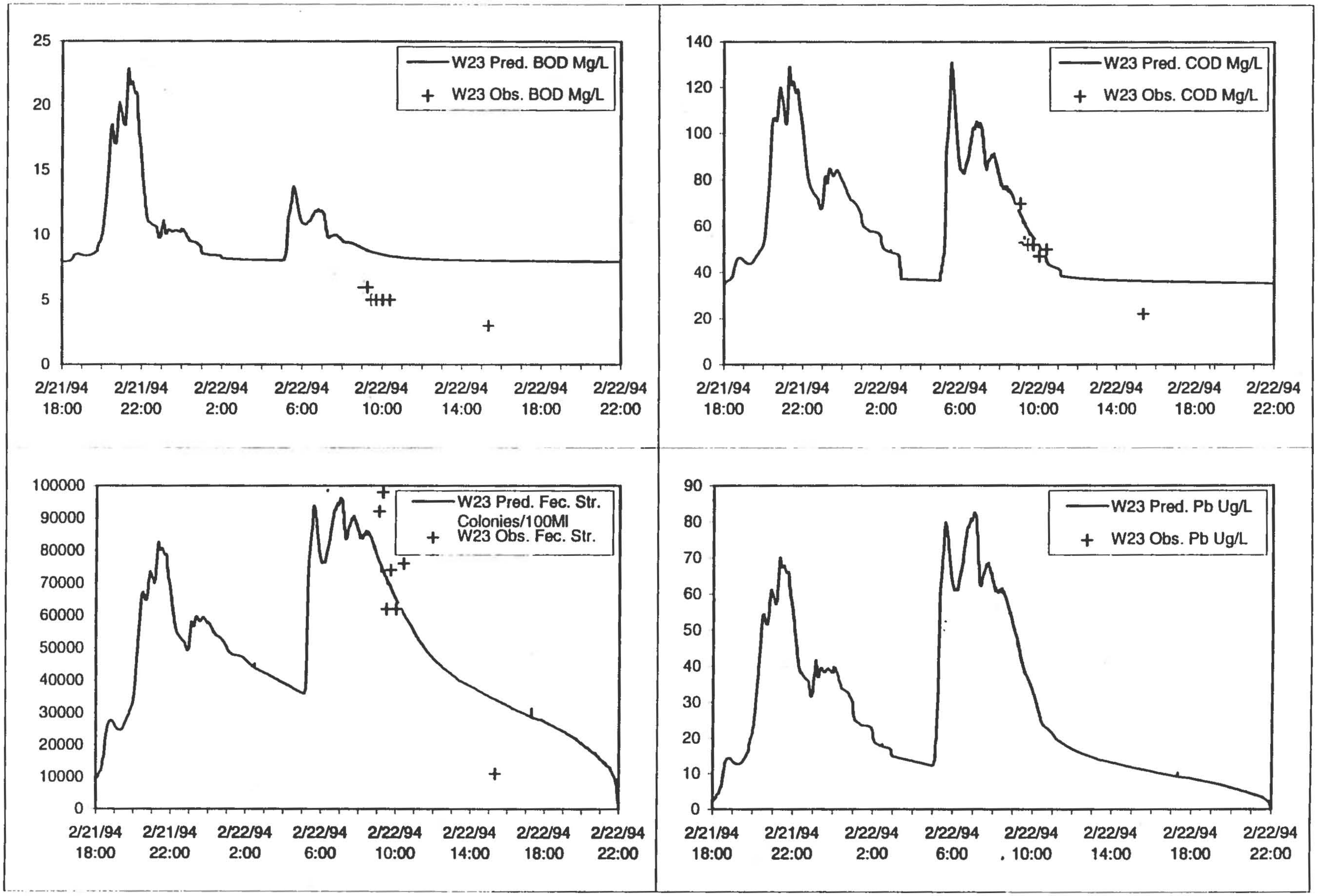


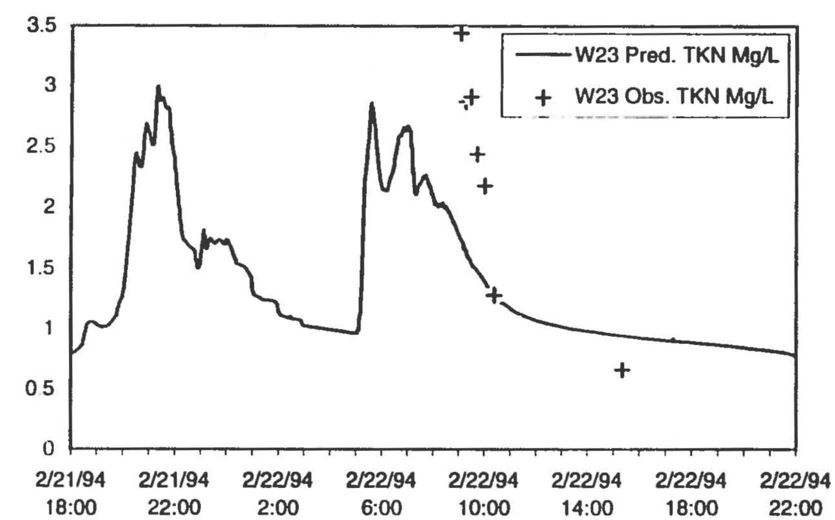


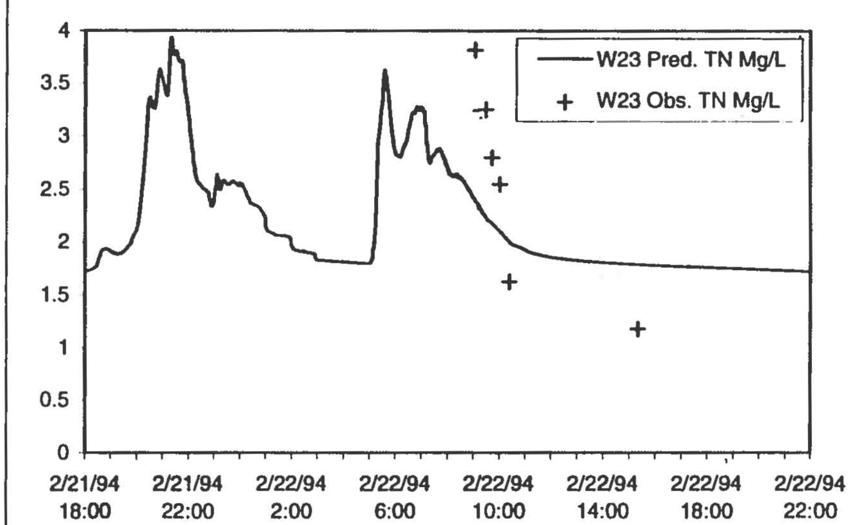
Appendix C
Observed and Predicted Pollutographs

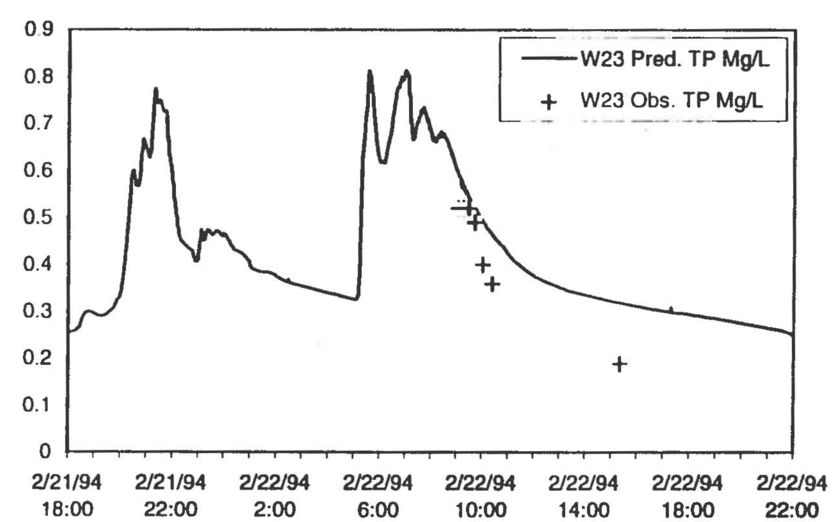


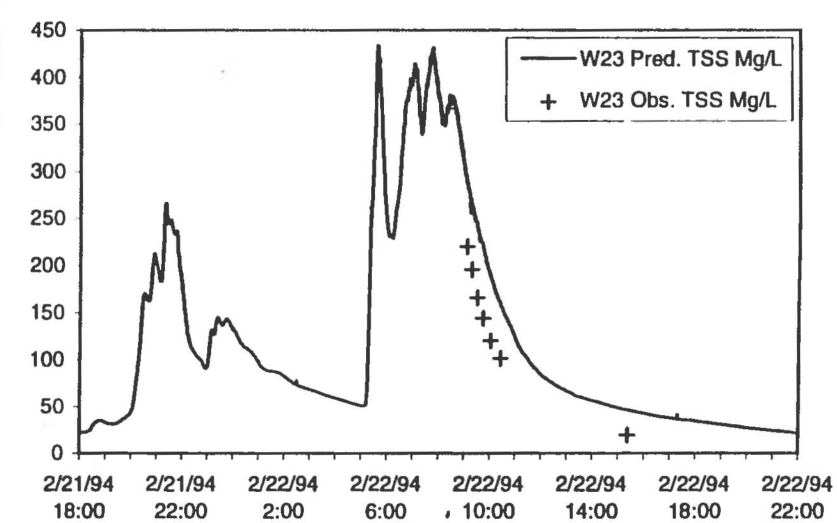
Appendix C
Observed and Predicted Pollutographs



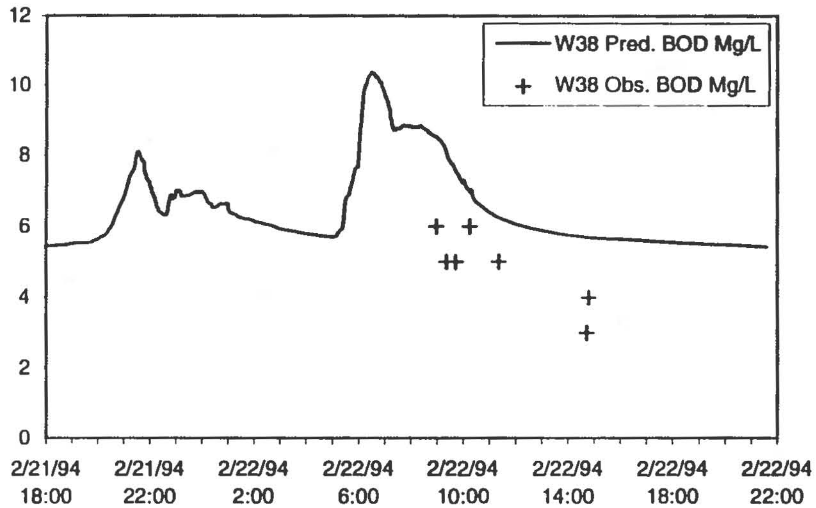

3.5
3
2.5
2
1.5
1
0.5
0
2/21/94 18:00
2/21/94 22:00
2/22/94 2:00
2/22/94 6:00
2/22/94 10:00
2/22/94 14:00
2/22/94 18:00
2/22/94 22:00
W23 Pred. TKN Mg/L
W23 Obs. TKN Mg/L

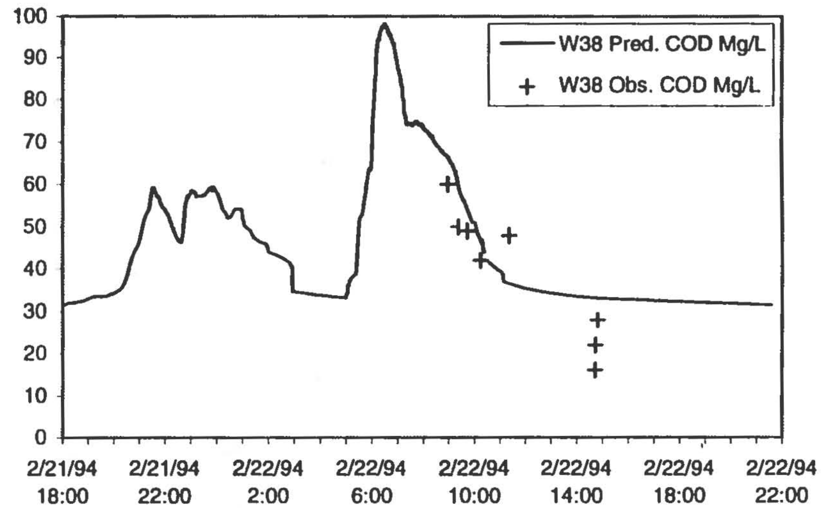

4
3.5
3
2.5
2
1.5
1
0.5
0
2/21/94 18:00
2/21/94 22:00
2/22/94 2:00
2/22/94 6:00
2/22/94 10:00
2/22/94 14:00
2/22/94 18:00
2/22/94 22:00
W23 Pred. TN Mg/L
W23 Obs. TN Mg/L

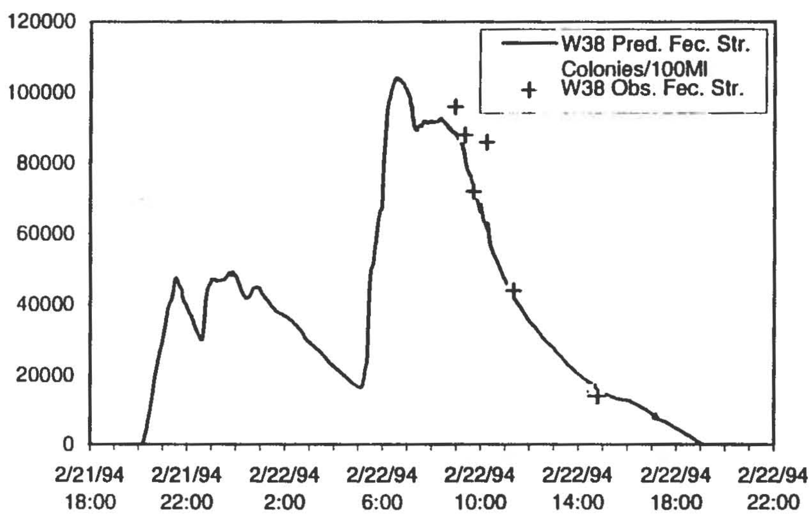

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2/21/94 18:00
2/21/94 22:00
2/22/94 2:00
2/22/94 6:00
2/22/94 10:00
2/22/94 14:00
2/22/94 18:00
2/22/94 22:00
W23 Pred. TP Mg/L
W23 Obs. TP Mg/L

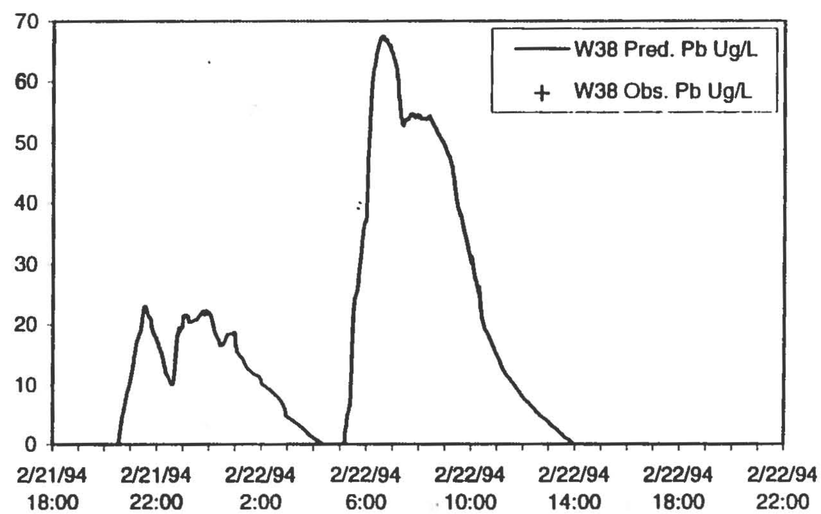

450
400
350
300
250
200
150
100
50
0
2/21/94 18:00
2/21/94 22:00
2/22/94 2:00
2/22/94 6:00
2/22/94 10:00
2/22/94 14:00
2/22/94 18:00
2/22/94 22:00
W23 Pred. TSS Mg/L
W23 Obs. TSS Mg/L

Appendix C
Observed and Predicted Pollutographs

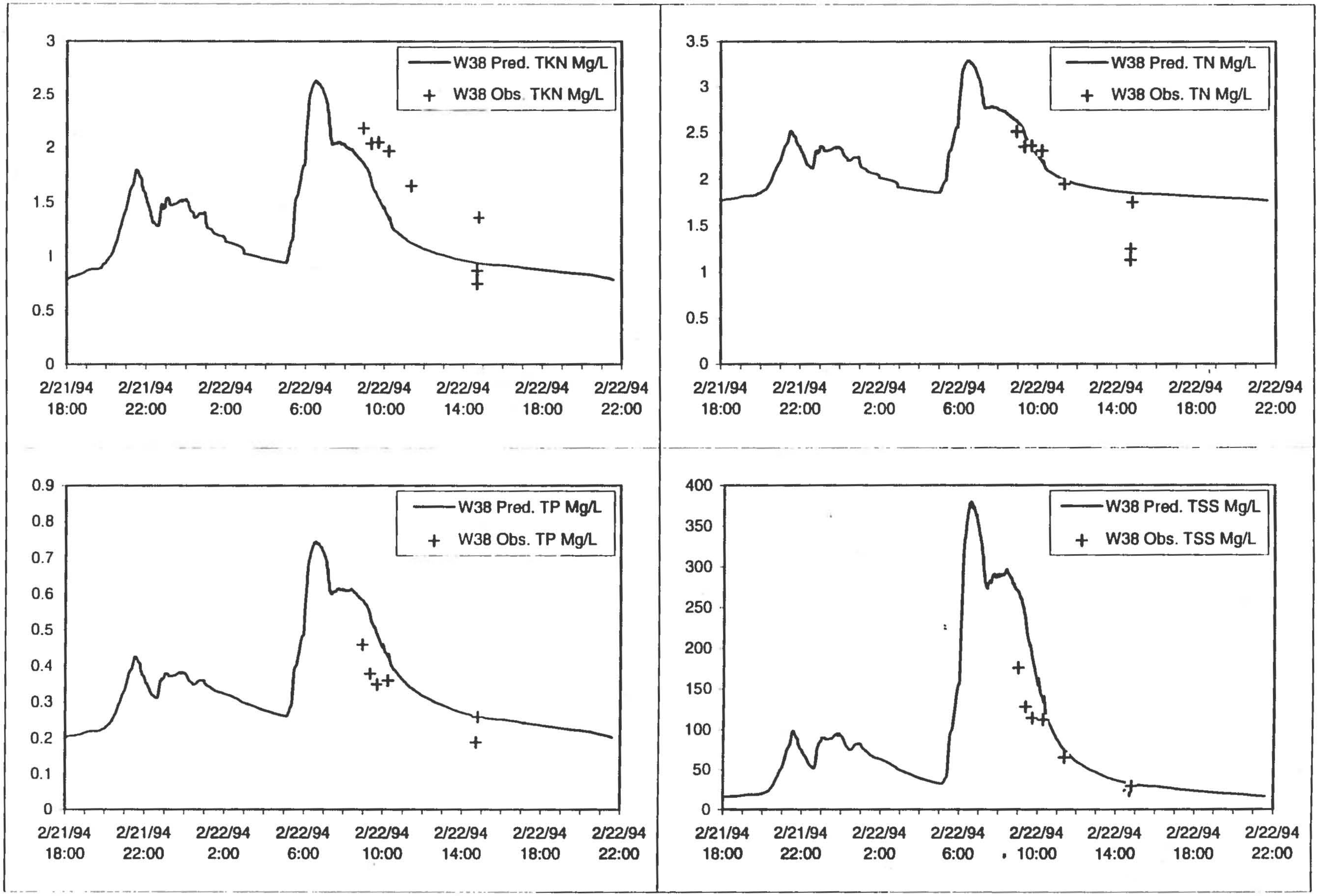




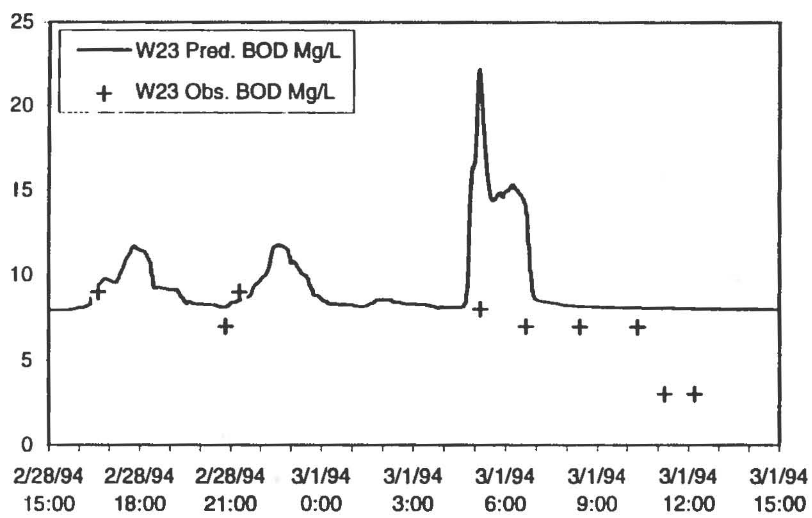


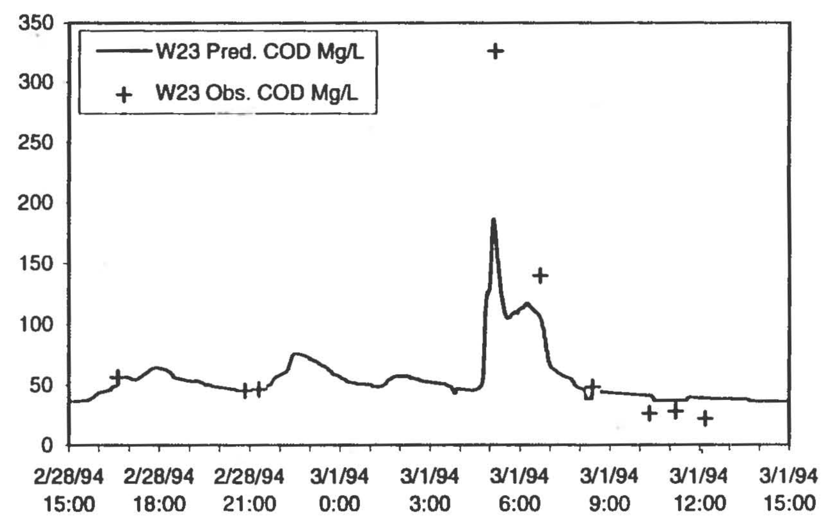


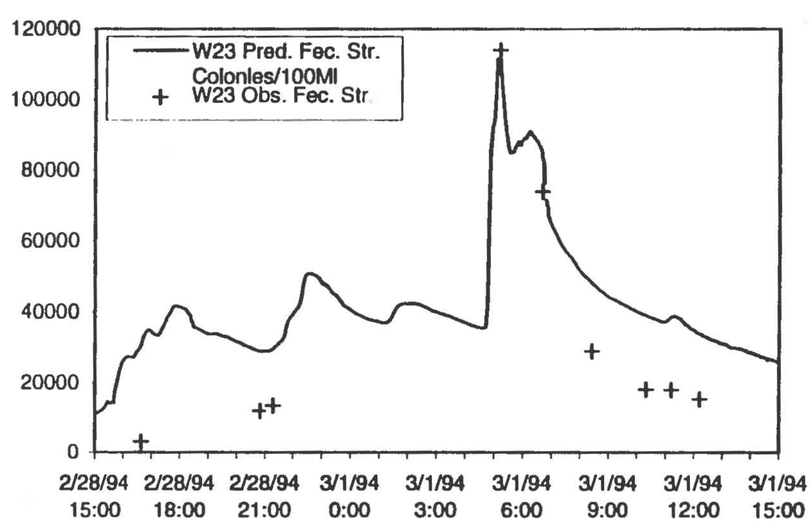
Appendix C
Observed and Predicted Pollutographs

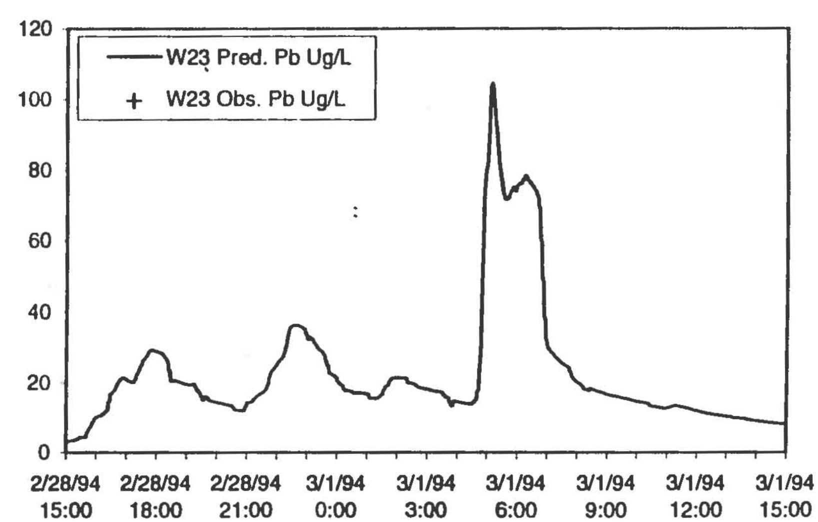


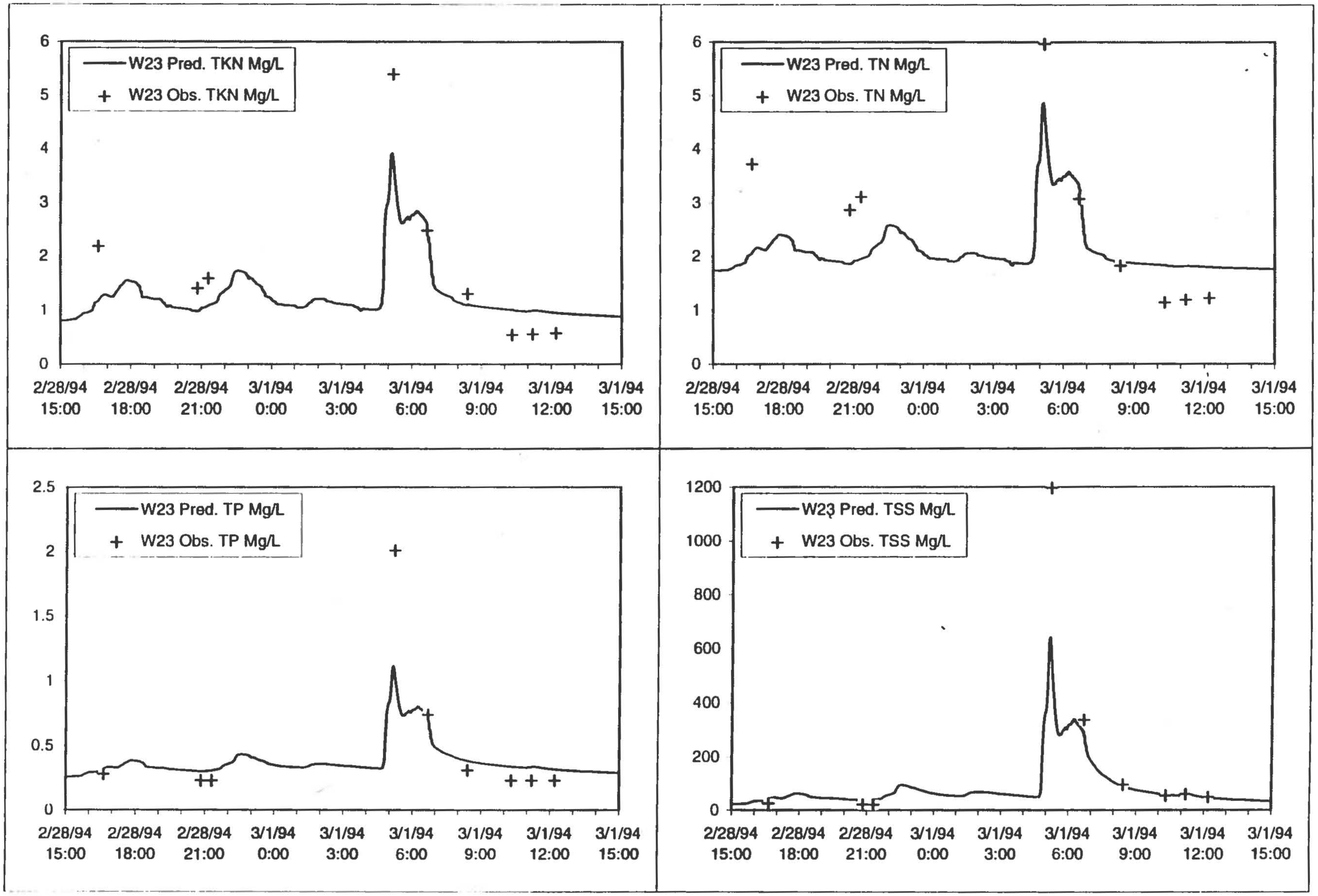
Appendix C
Observed and Predicted Pollutographs



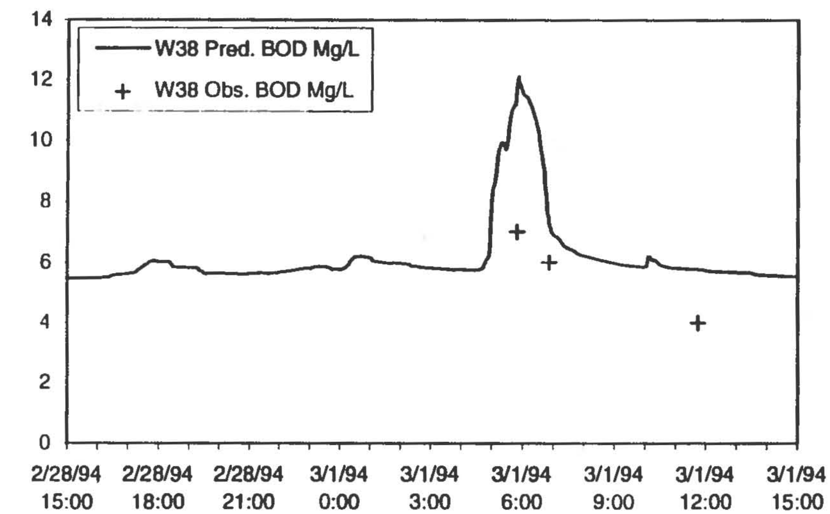


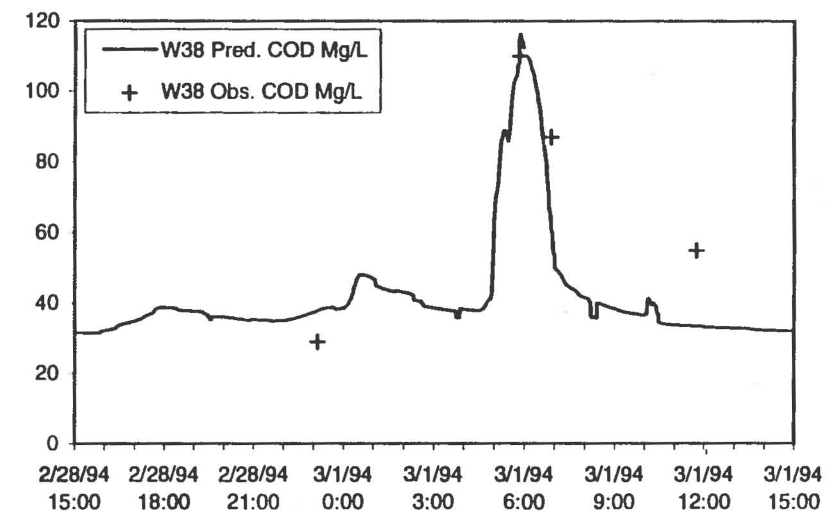


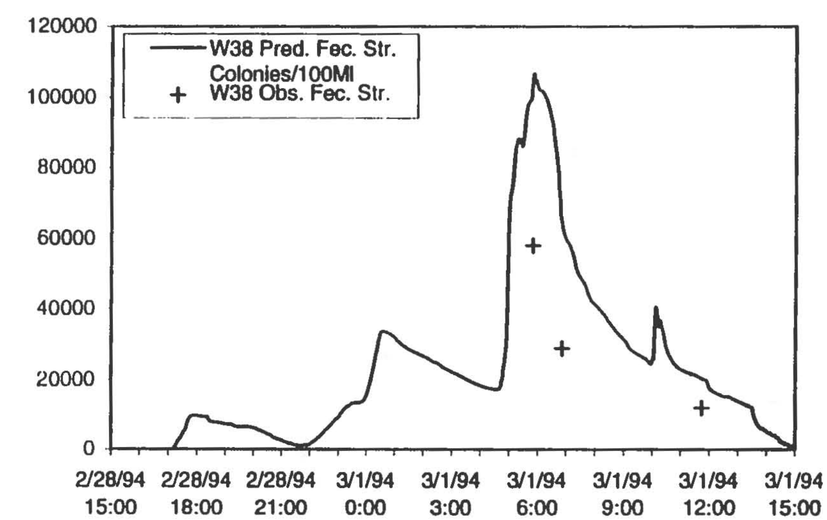


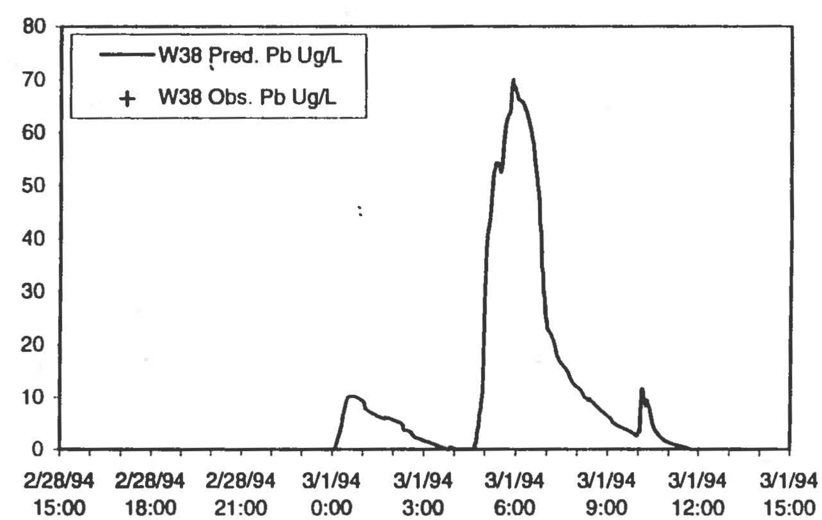

W23 Pred. TKN Mg/L
W23 Obs. TKN Mg/L
W23 Pred. TN Mg/L
W23 Obs. TN Mg/L
W23 Pred. TP Mg/L
W23 Obs. TP Mg/L
W23 Pred. TSS Mg/L
W23 Obs. TSS Mg/L
2/28/94 15:00
2/28/94 18:00
2/28/94 21:00
3/1/94 0:00
3/1/94 3:00
3/1/94 6:00
3/1/94 9:00
3/1/94 12:00
3/1/94 15:00

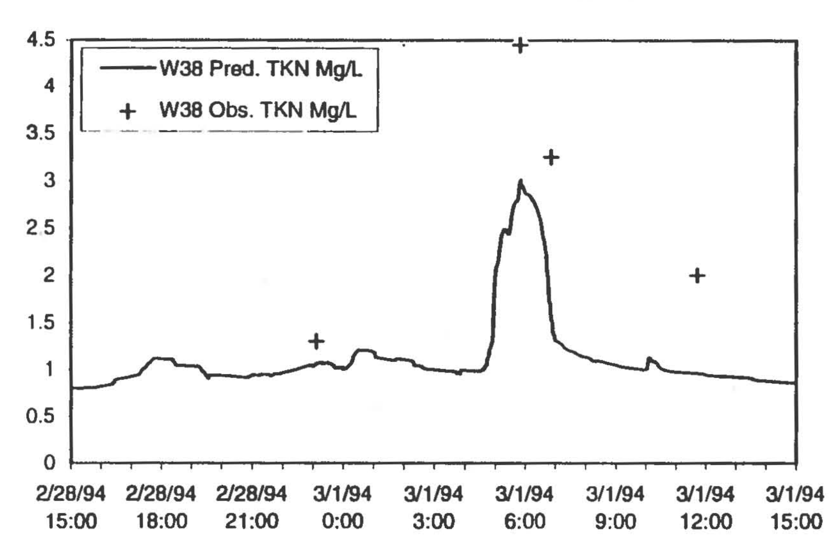
Appendix C
Observed and Predicted Pollutographs

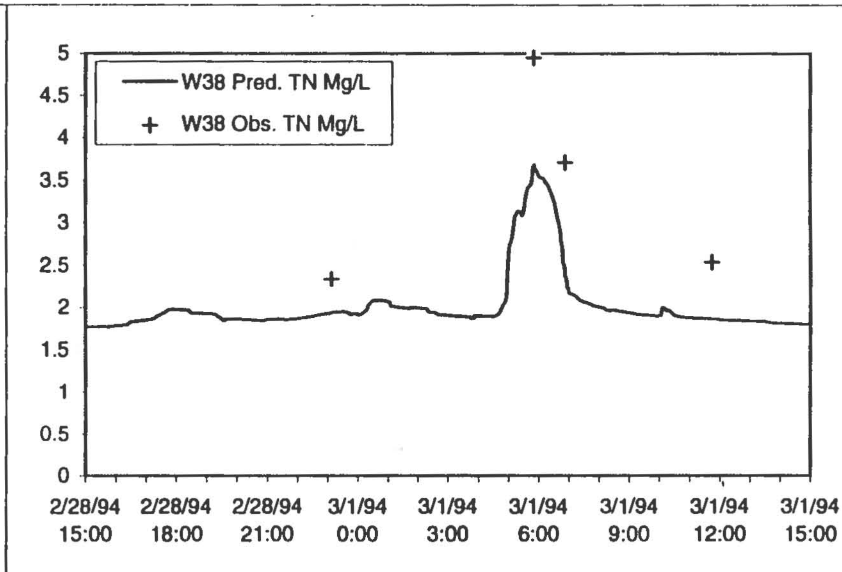


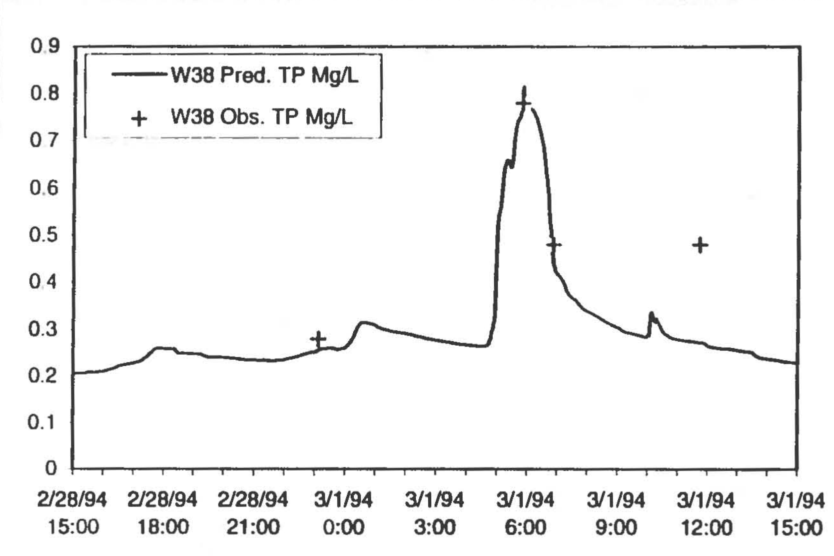


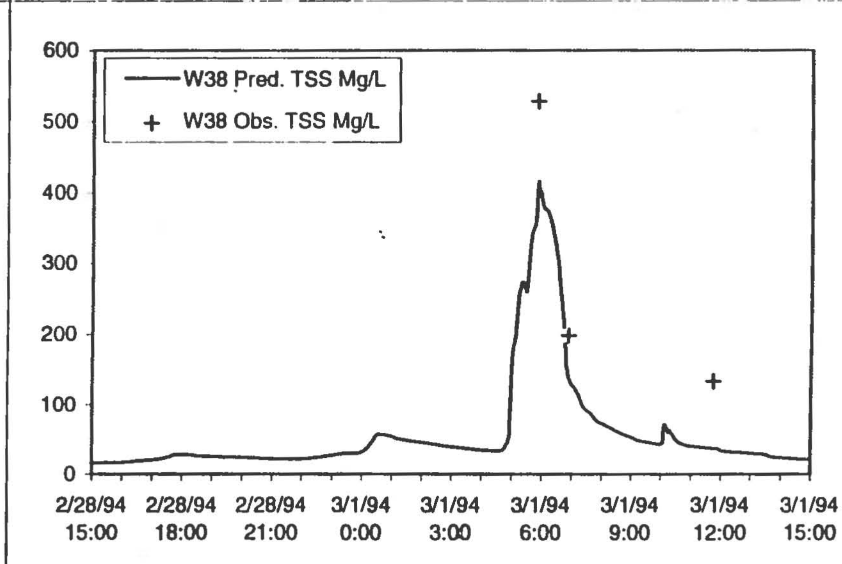




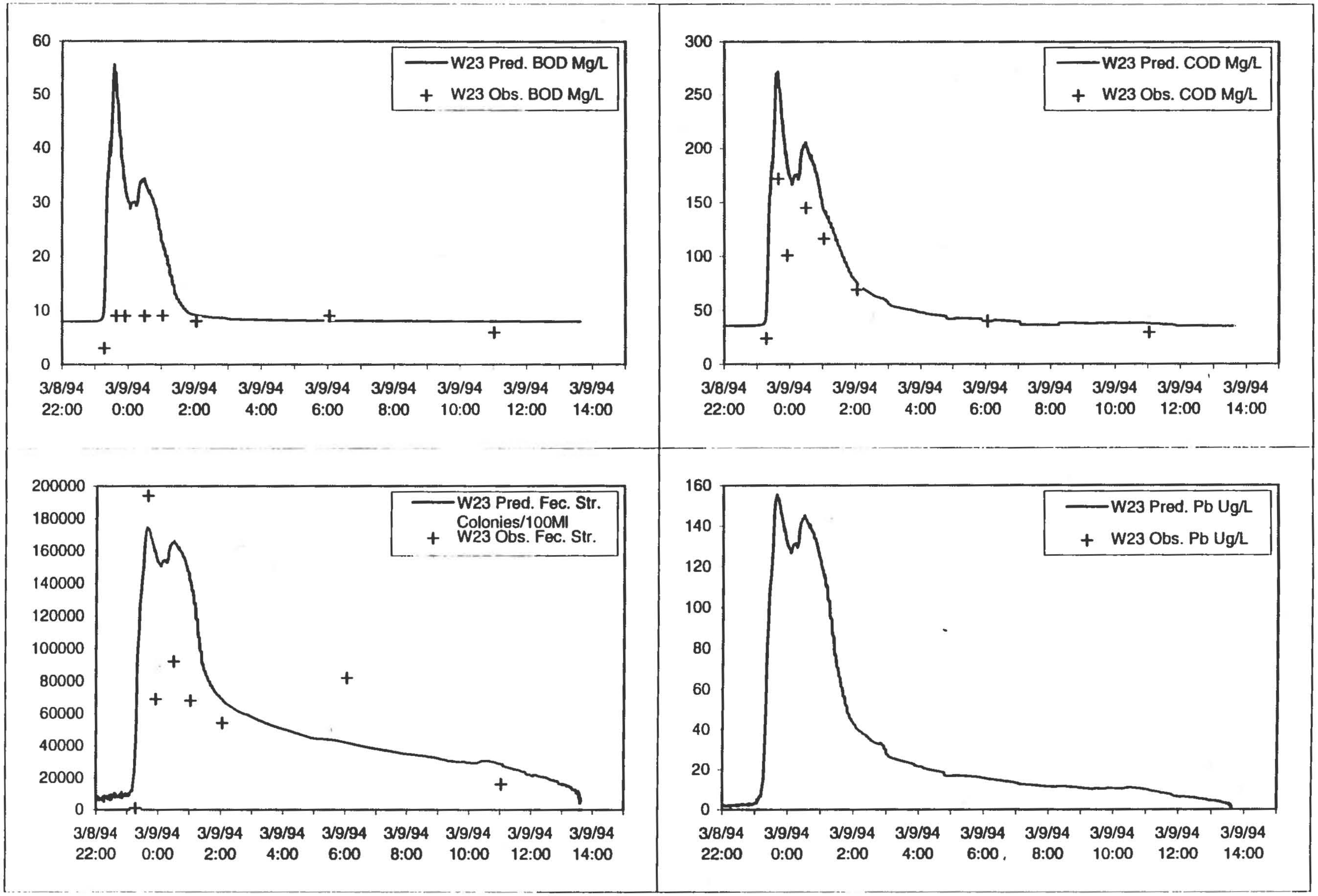

W38 Pred. TKN Mg/L
W38 Obs. TKN Mg/L
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2/28/94 15:00
2/28/94 18:00
2/28/94 21:00
3/1/94 0:00
3/1/94 3:00
3/1/94 6:00
3/1/94 9:00
3/1/94 12:00
3/1/94 15:00


W38 Pred. TN Mg/L
W38 Obs. TN Mg/L
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2/28/94 15:00
2/28/94 18:00
2/28/94 21:00
3/1/94 0:00
3/1/94 3:00
3/1/94 6:00
3/1/94 9:00
3/1/94 12:00
3/1/94 15:00

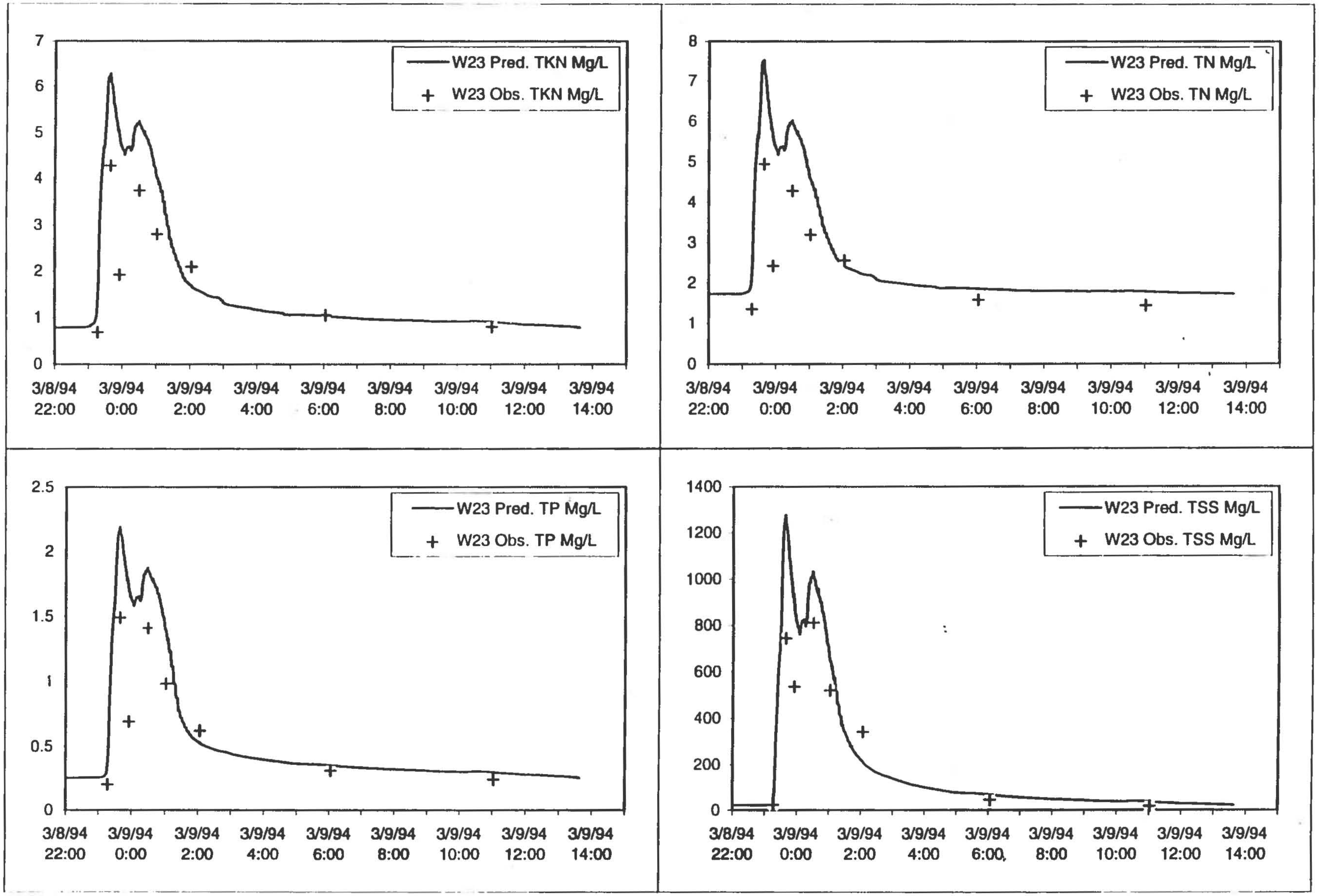

W38 Pred. TP Mg/L
W38 Obs. TP Mg/L
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2/28/94 15:00
2/28/94 18:00
2/28/94 21:00
3/1/94 0:00
3/1/94 3:00
3/1/94 6:00
3/1/94 9:00
3/1/94 12:00
3/1/94 15:00


W38 Pred. TSS Mg/L
W38 Obs. TSS Mg/L
600
500
400
300
200
100
0
2/28/94 15:00
2/28/94 18:00
2/28/94 21:00
3/1/94 0:00
3/1/94 3:00
3/1/94 6:00
3/1/94 9:00
3/1/94 12:00
3/1/94 15:00

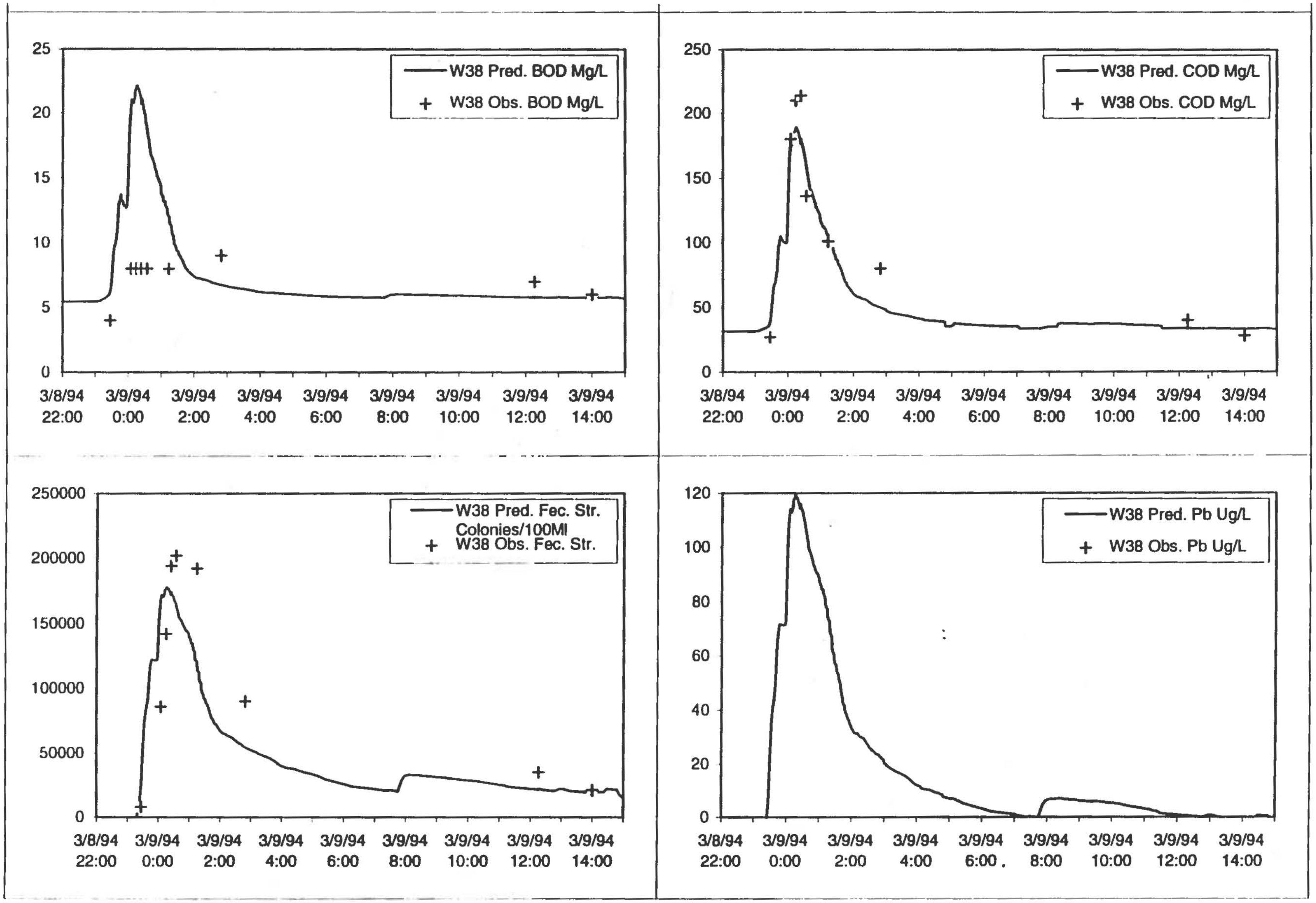
Appendix C
Observed and Predicted Pollutographs



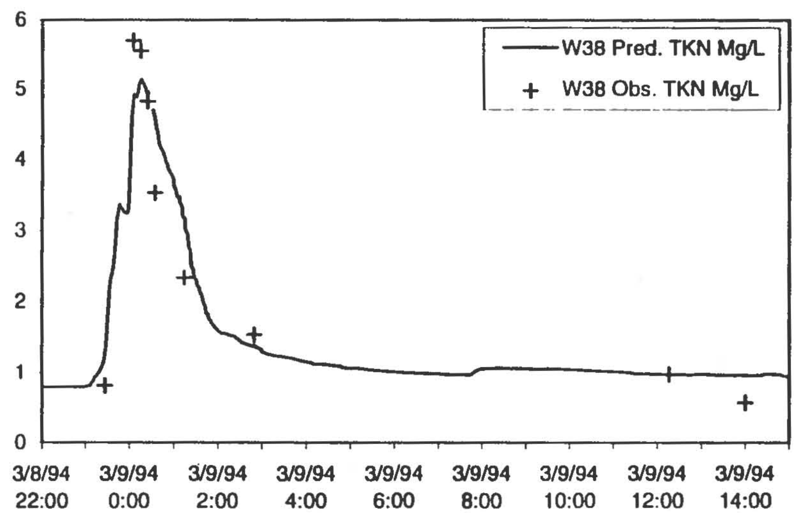
Appendix C
Observed and Predicted Pollutographs

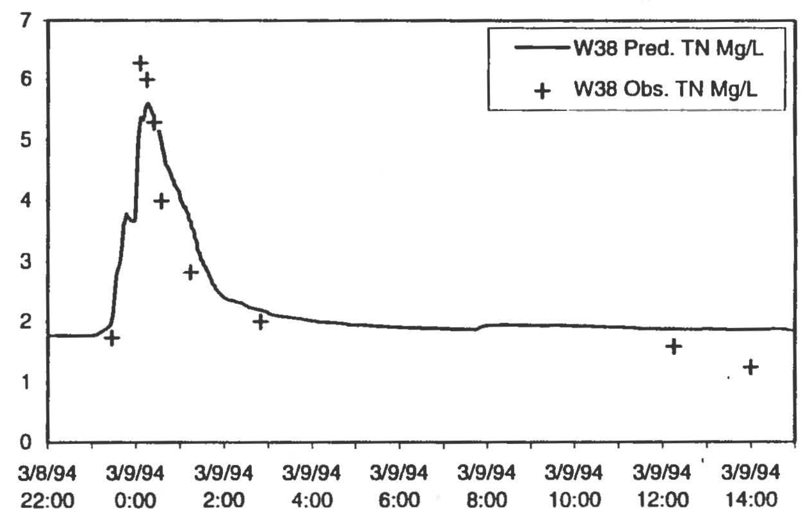


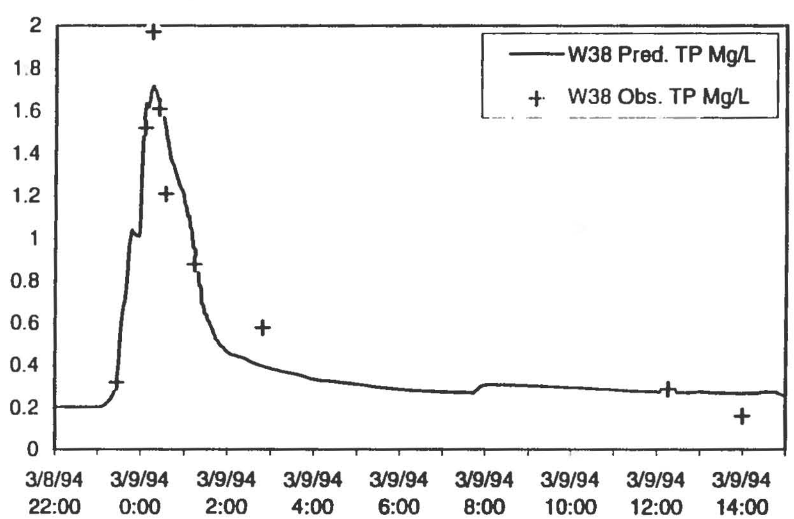
Appendix C
Observed and Predicted Pollutographs

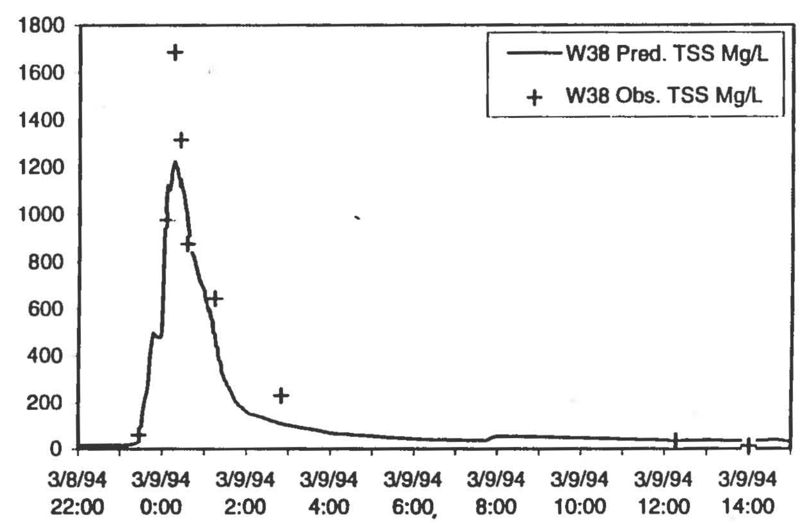


Appendix C
Observed and Predicted Pollutographs

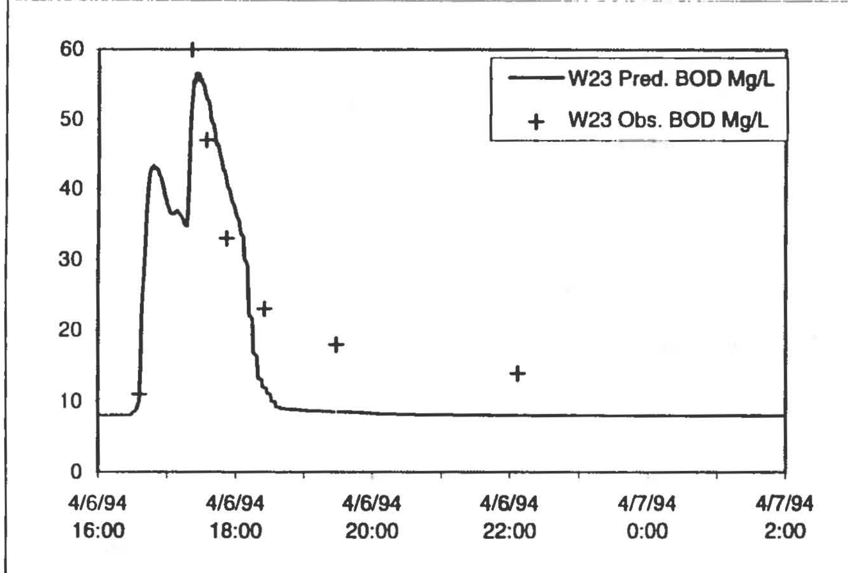


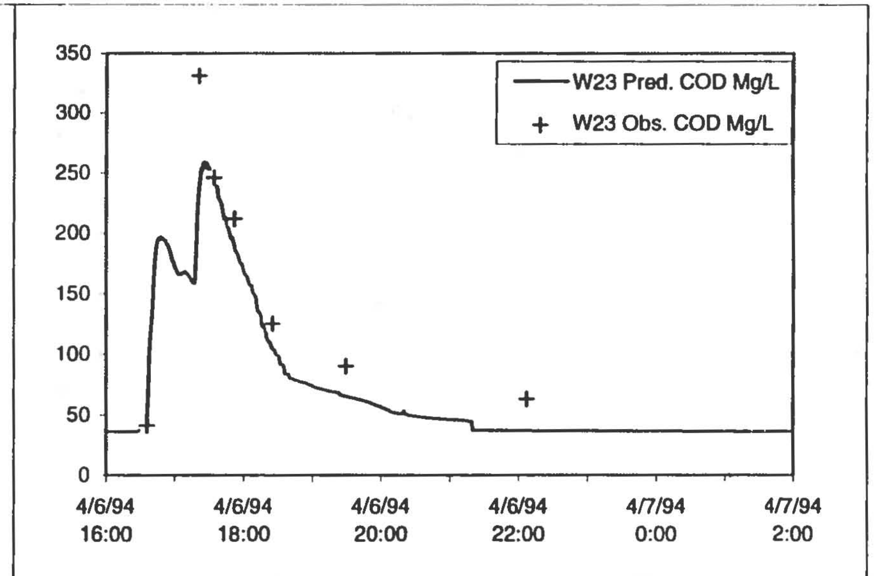


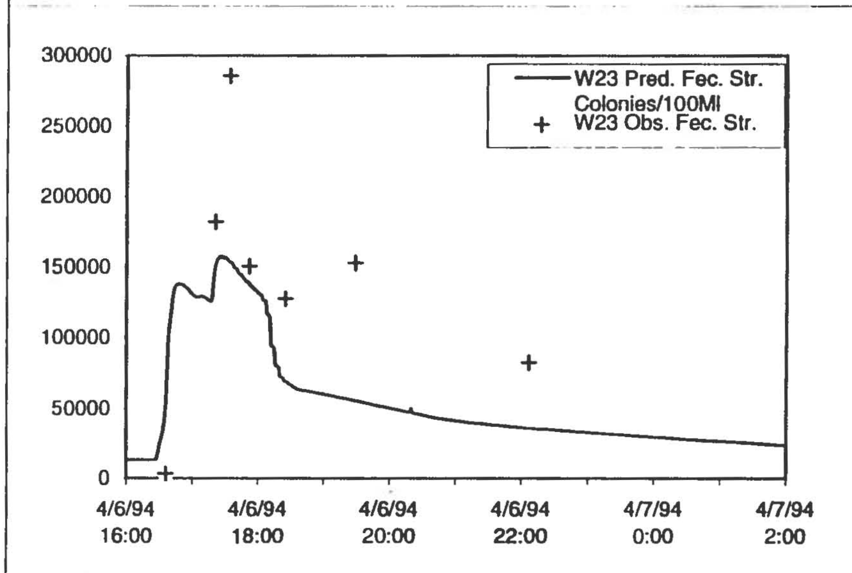


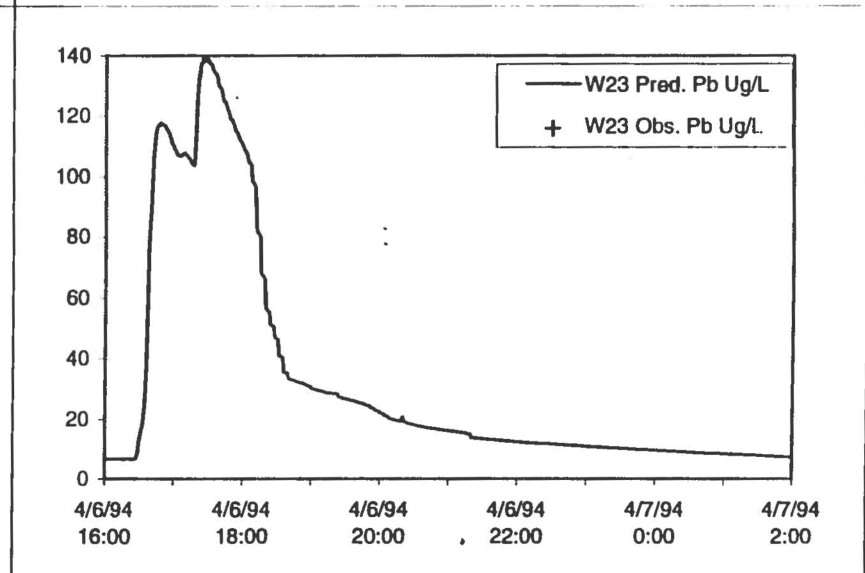


Appendix C
Observed and Predicted Pollutographs

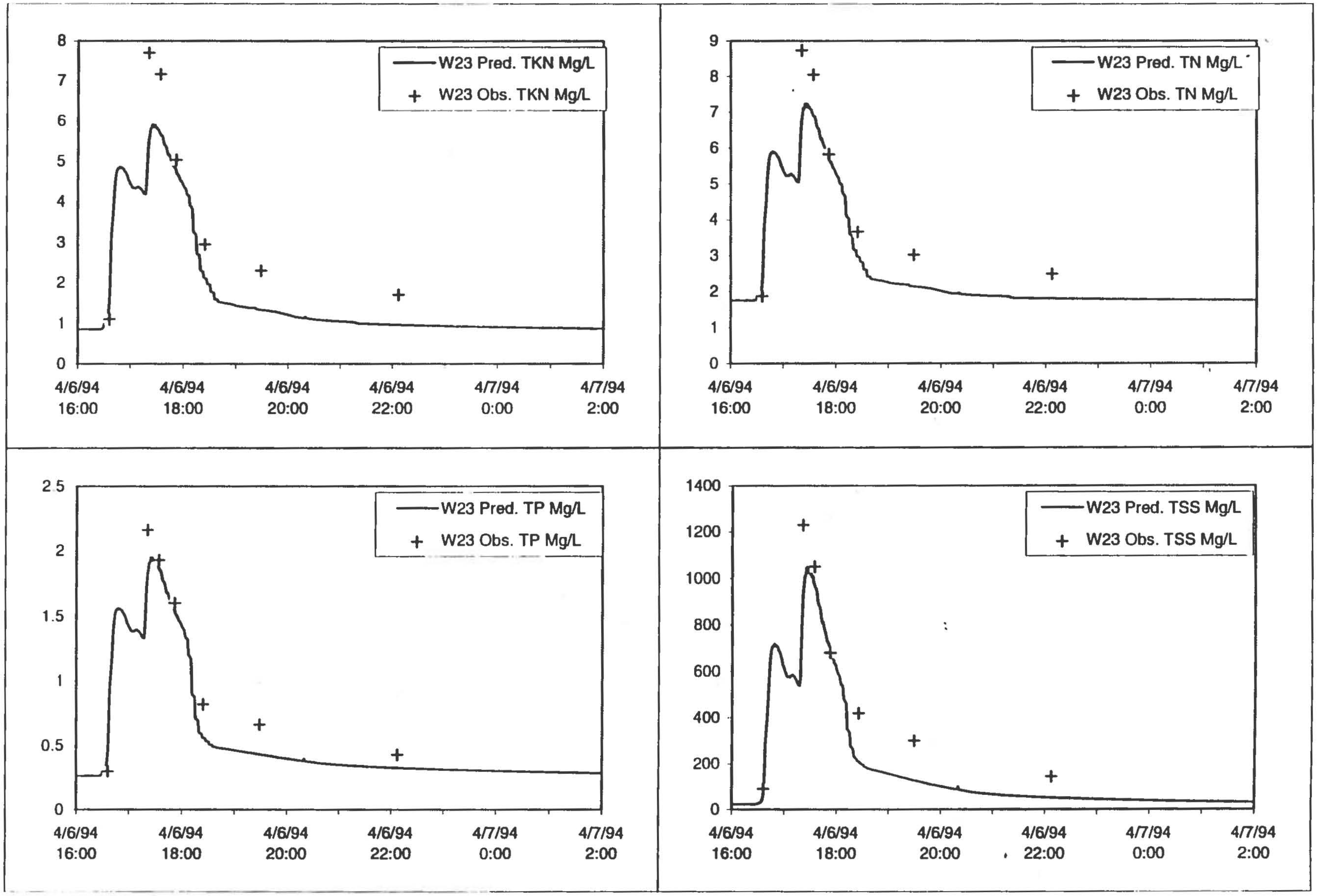




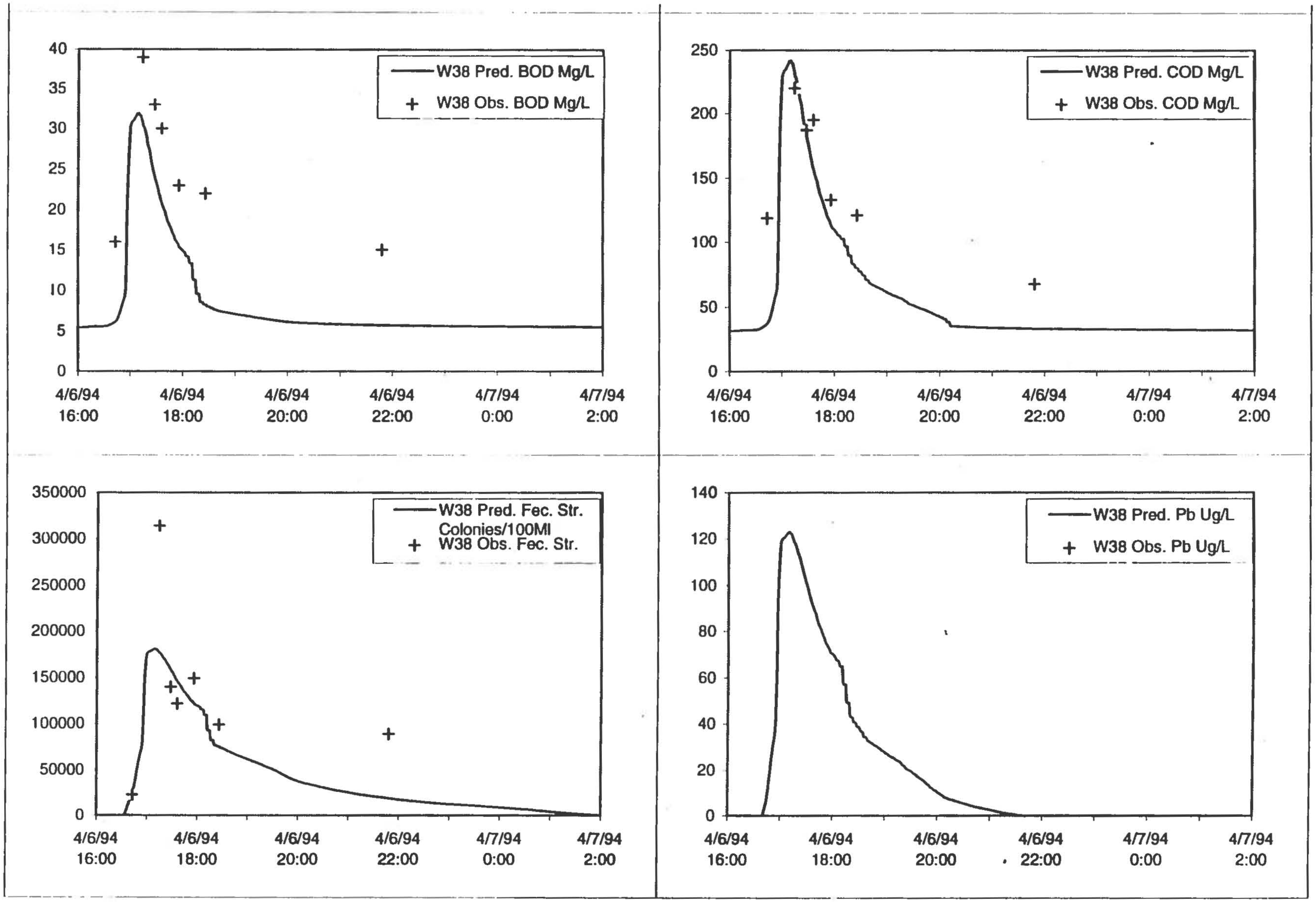


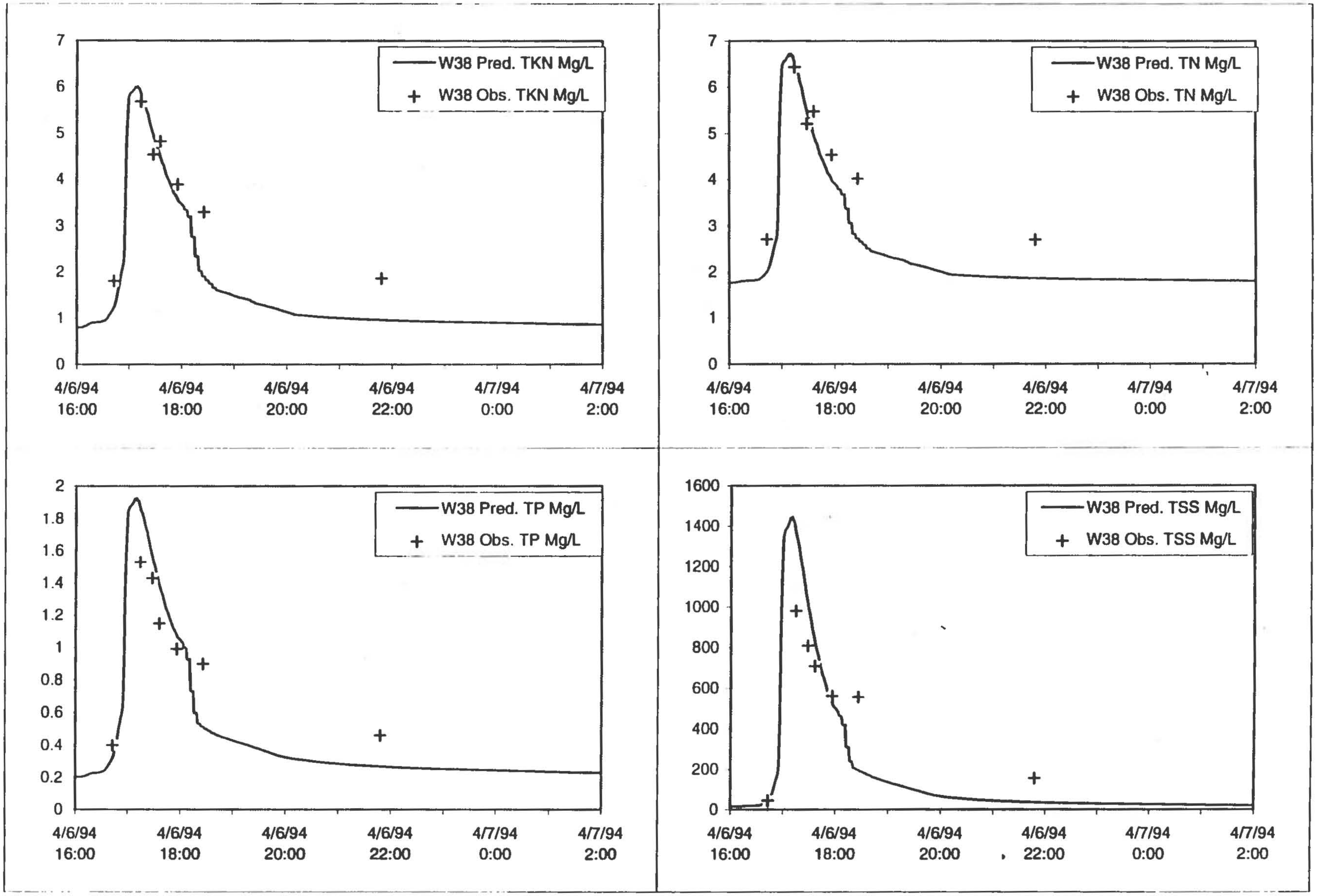


Appendix C
Observed and Predicted Pollutographs

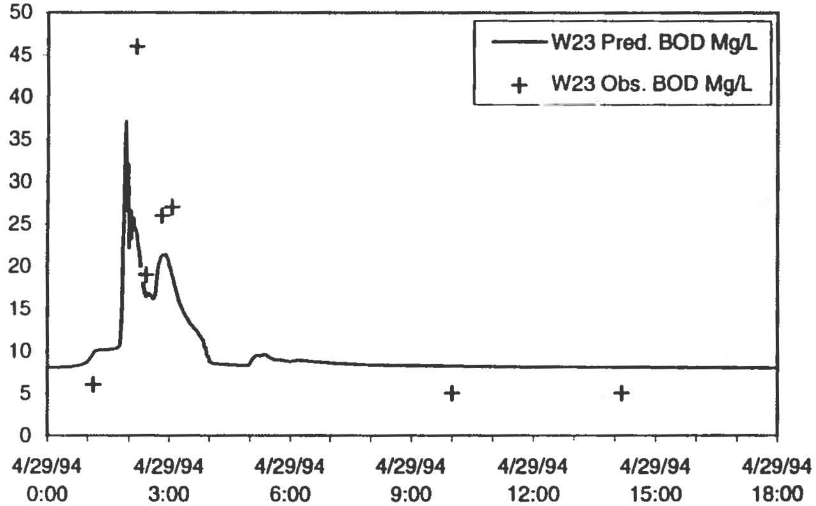


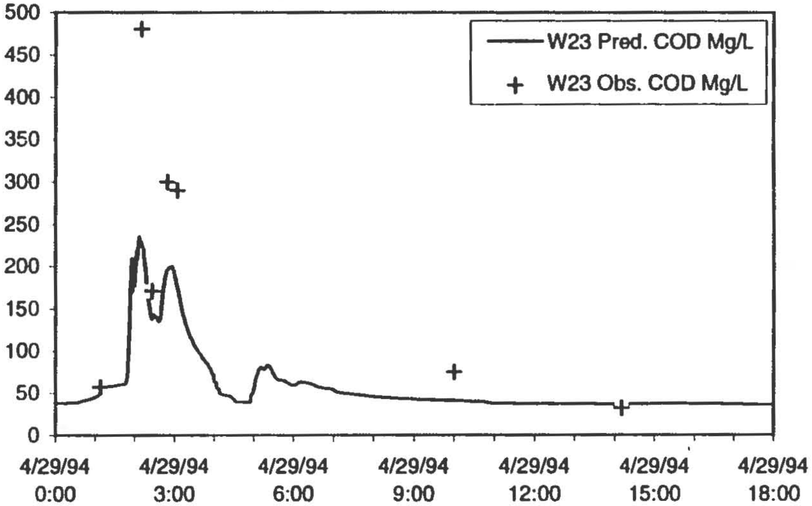
Appendix C
Observed and Predicted Pollutographs

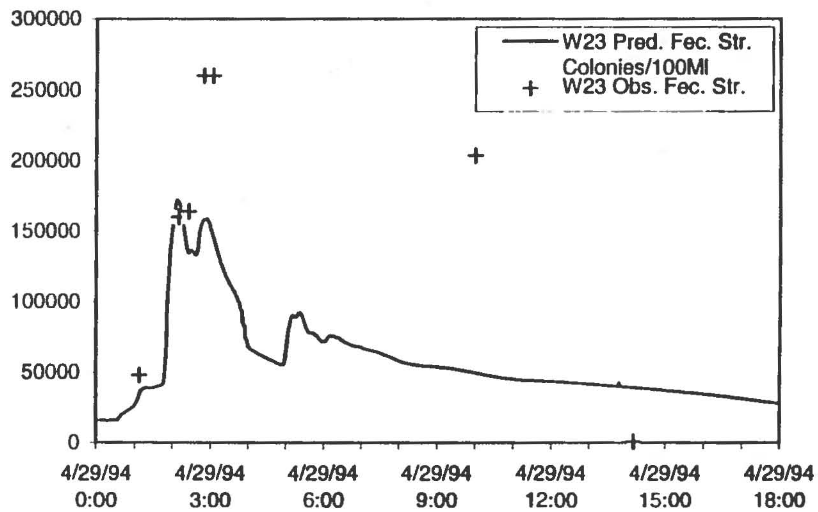


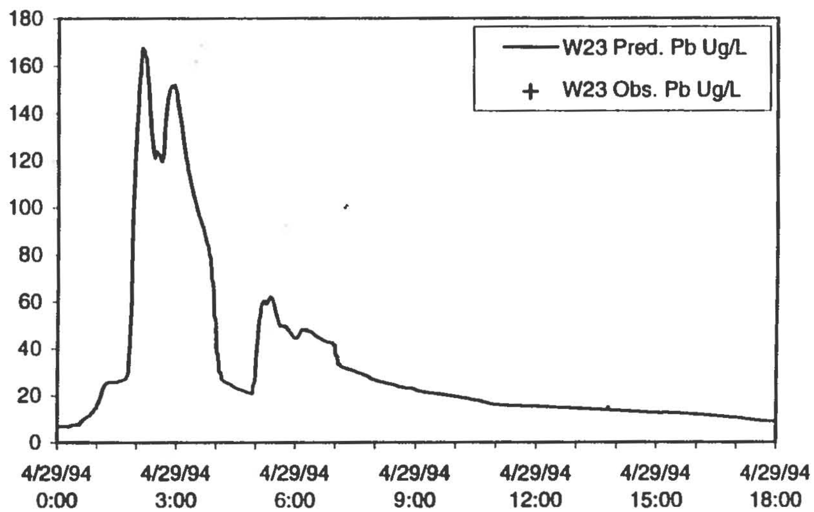

W38 Pred. TKN Mg/L
W38 Obs. TKN Mg/L
W38 Pred. TN Mg/L
W38 Obs. TN Mg/L
W38 Pred. TP Mg/L
W38 Obs. TP Mg/L
W38 Pred. TSS Mg/L
W38 Obs. TSS Mg/L
4/6/94 16:00
4/6/94 18:00
4/6/94 20:00
4/6/94 22:00
4/7/94 0:00
4/7/94 2:00

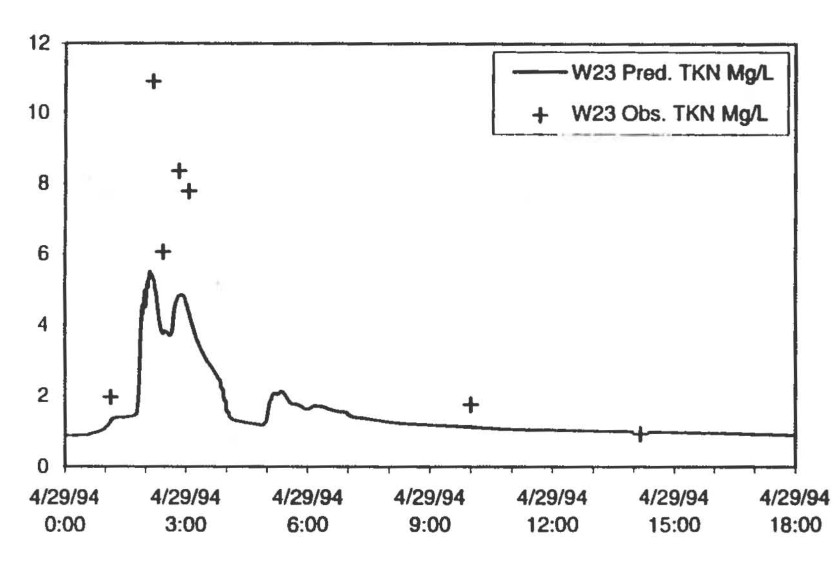
Appendix C
Observed and Predicted Pollutographs

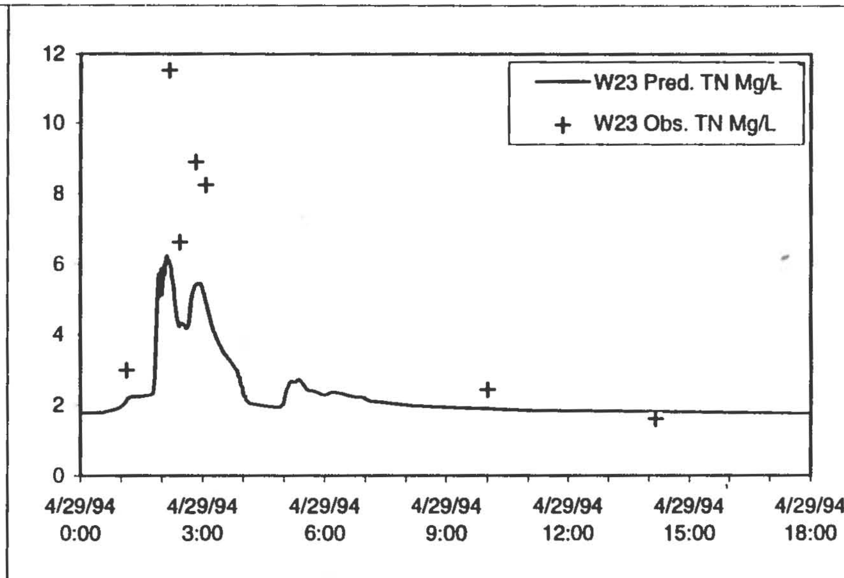


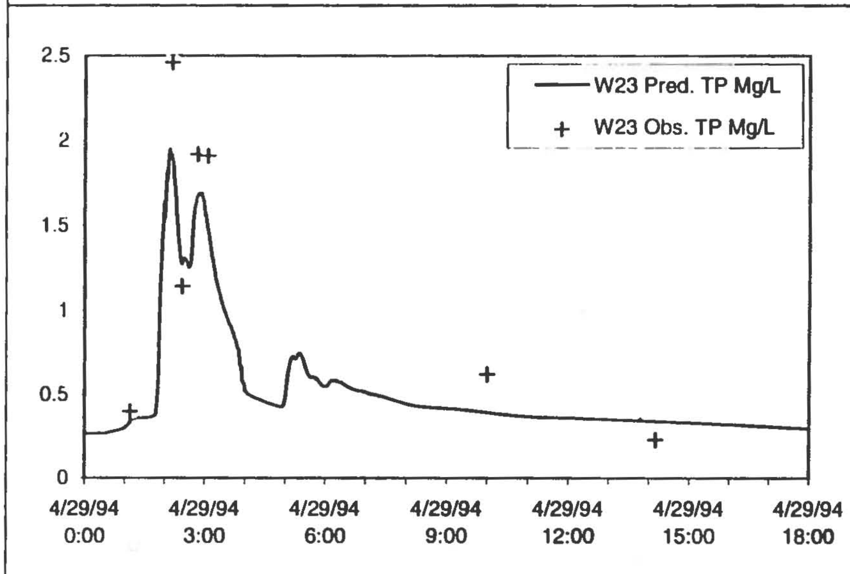


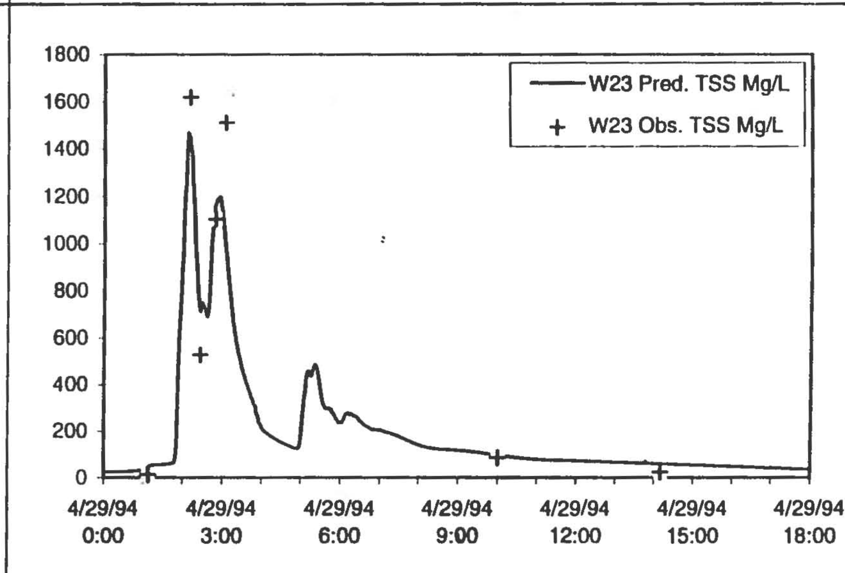




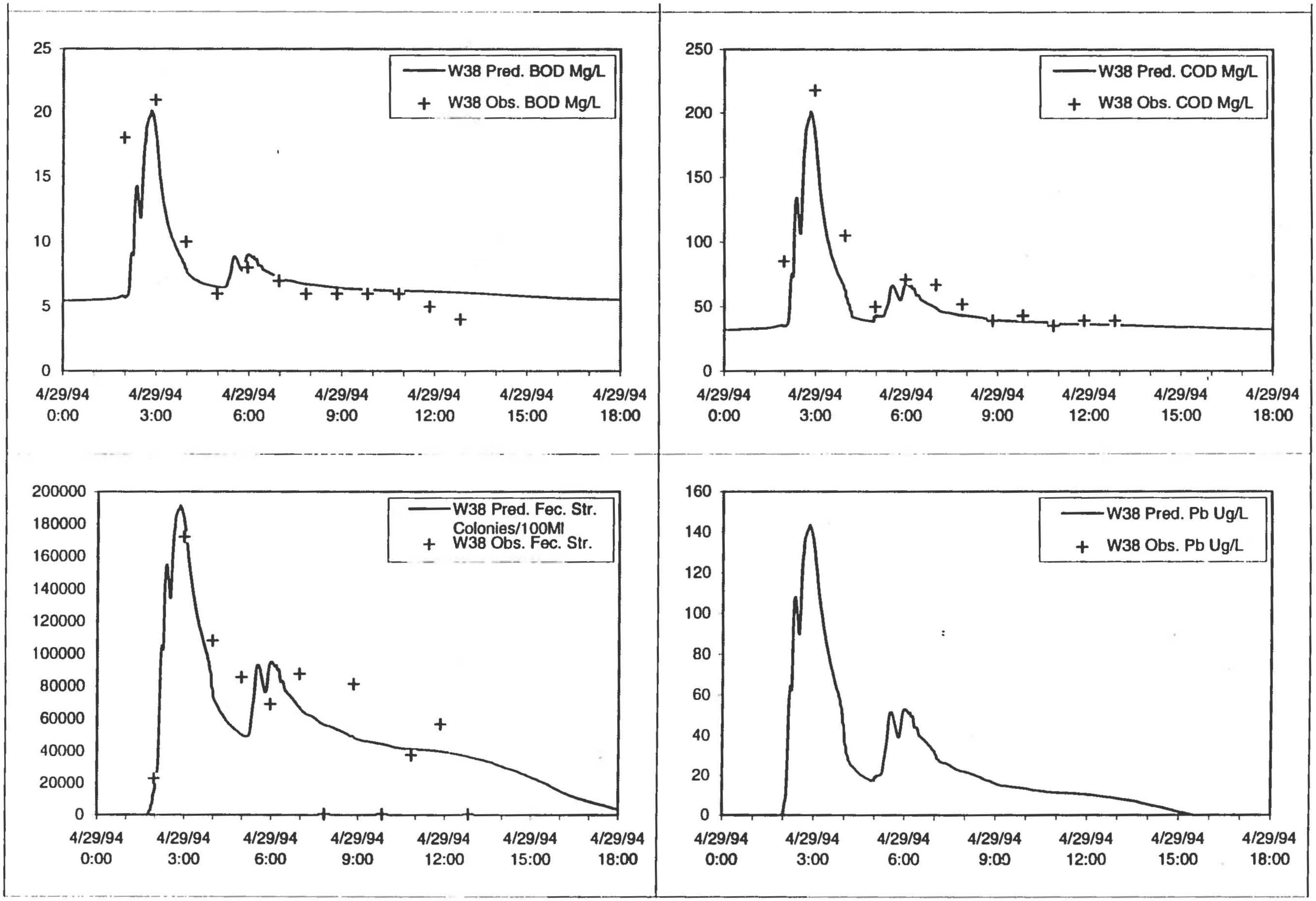

W23 Pred. TKN Mg/L
W23 Obs. TKN Mg/L
12
10
8
6
4
2
0
4/29/94 0:00
4/29/94 3:00
4/29/94 6:00
4/29/94 9:00
4/29/94 12:00
4/29/94 15:00
4/29/94 18:00


W23 Pred. TN Mg/L
W23 Obs. TN Mg/L
12
10
8
6
4
2
0
4/29/94 0:00
4/29/94 3:00
4/29/94 6:00
4/29/94 9:00
4/29/94 12:00
4/29/94 15:00
4/29/94 18:00

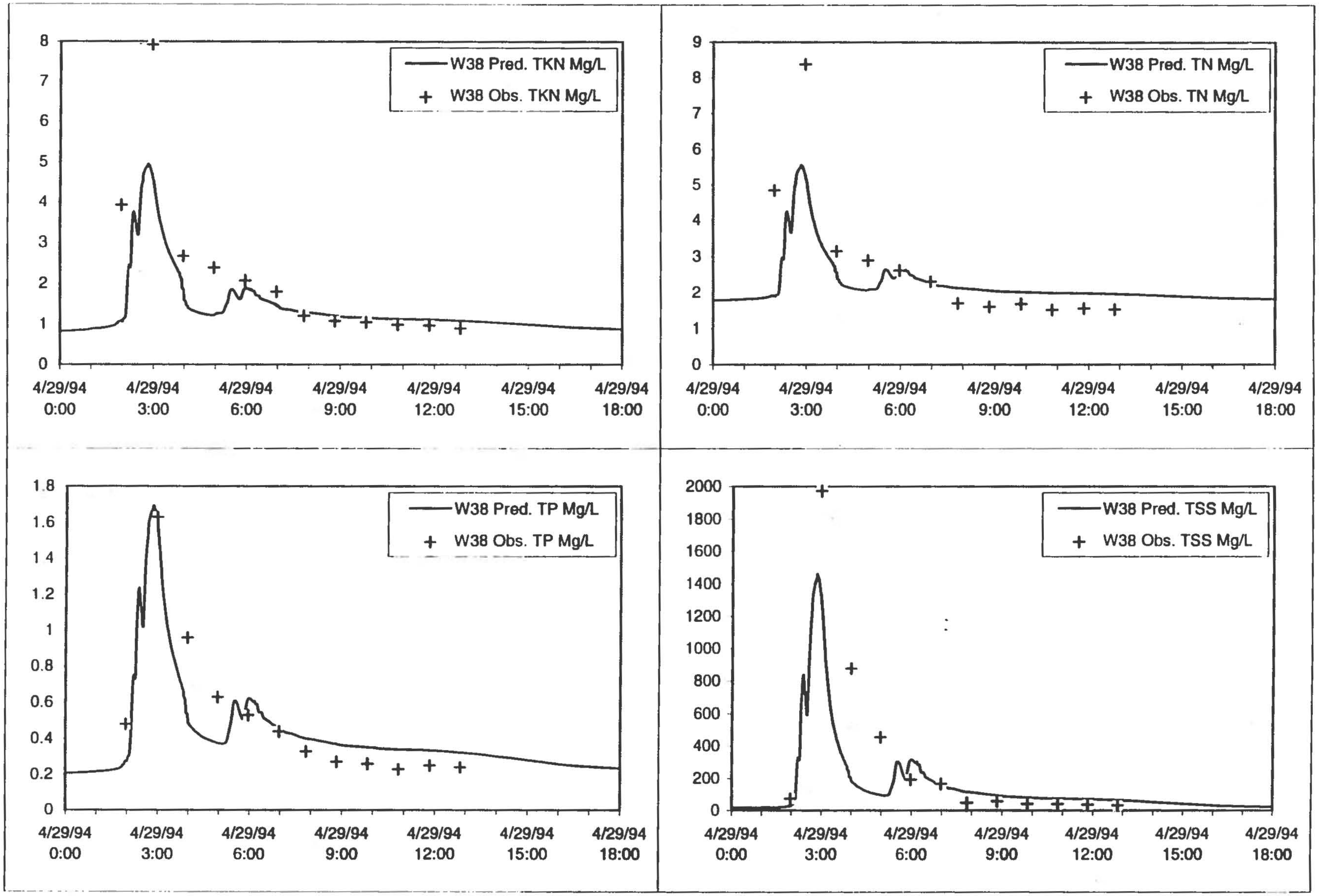

W23 Pred. TP Mg/L
W23 Obs. TP Mg/L
2.5
2
1.5
1
0.5
0
4/29/94 0:00
4/29/94 3:00
4/29/94 6:00
4/29/94 9:00
4/29/94 12:00
4/29/94 15:00
4/29/94 18:00


W23 Pred. TSS Mg/L
W23 Obs. TSS Mg/L
1800
1600
1400
1200
1000
800
600
400
200
0
4/29/94 0:00
4/29/94 3:00
4/29/94 6:00
4/29/94 9:00
4/29/94 12:00
4/29/94 15:00
4/29/94 18:00

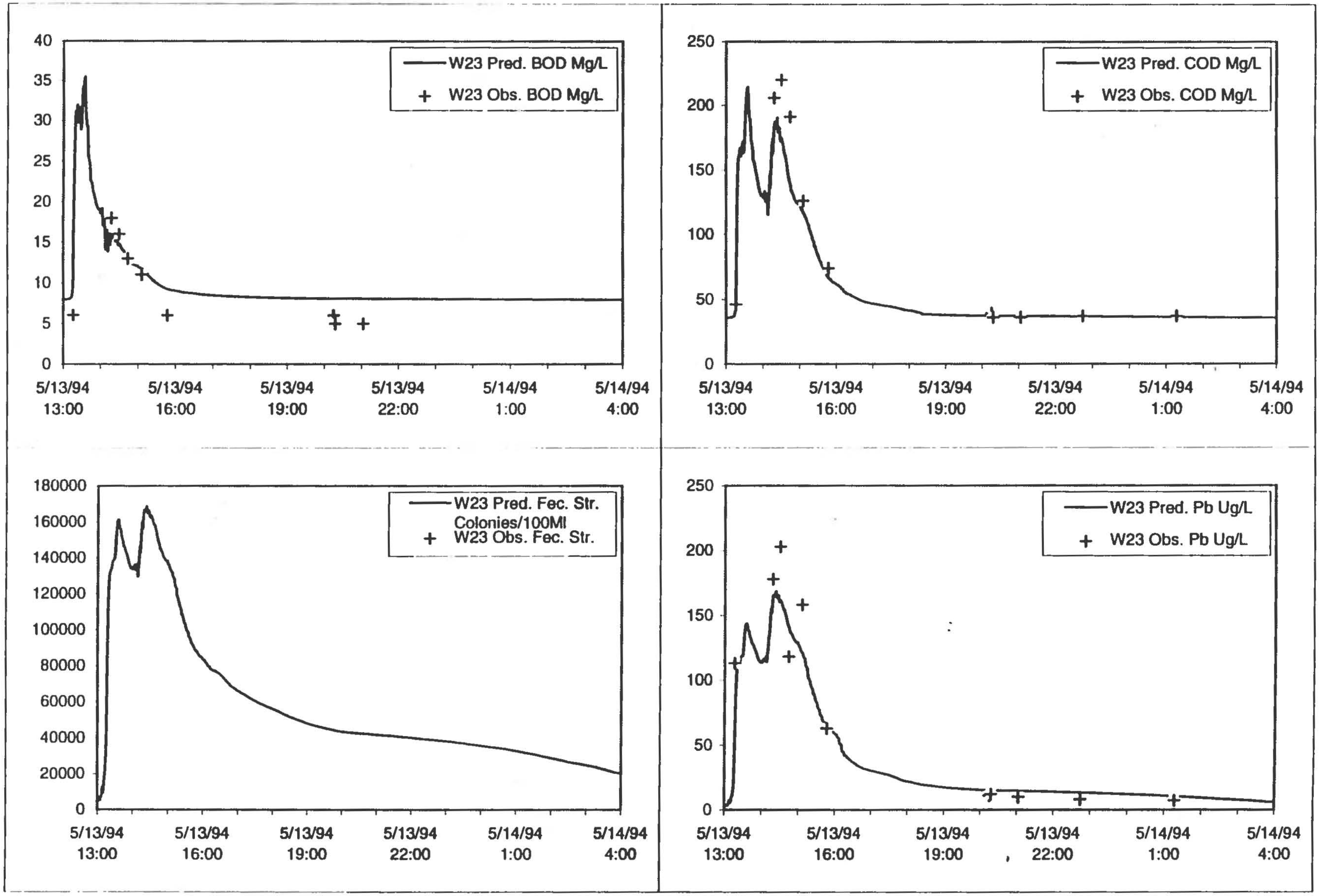
Observed and Predicted Pollutographs



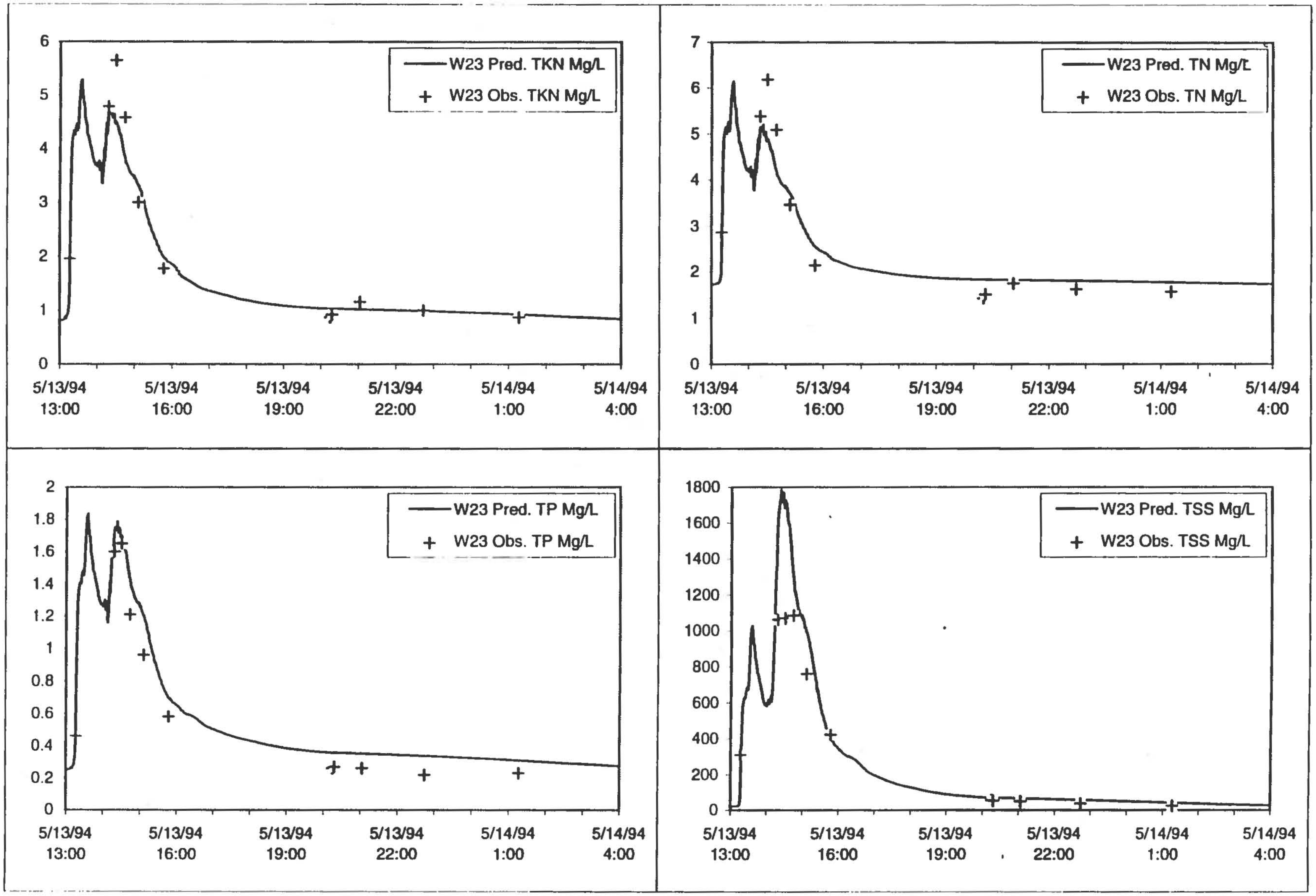
Appendix C
Observed and Predicted Pollutographs

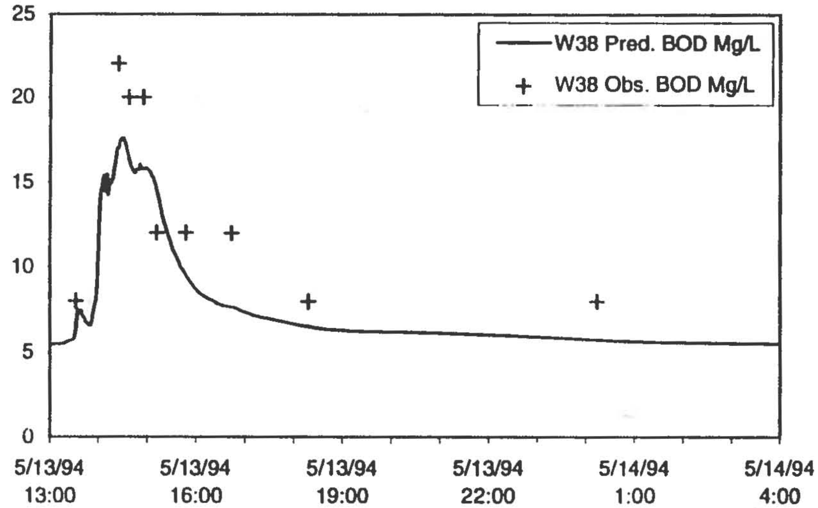


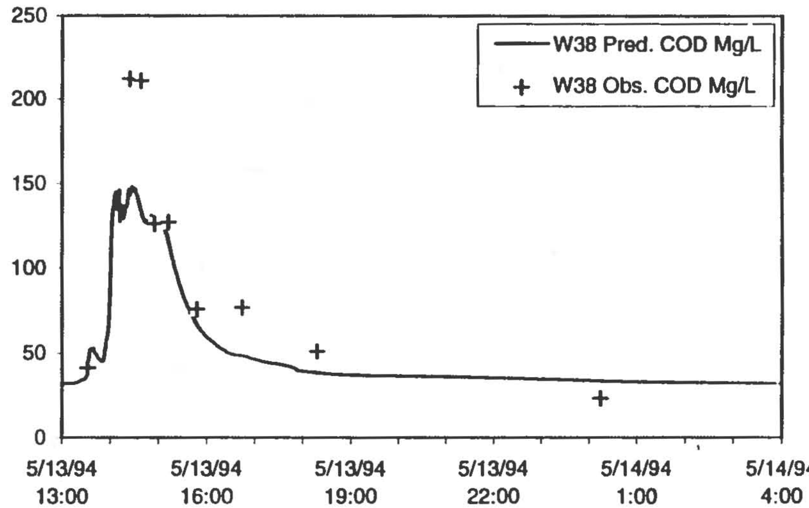
Appendix C
Observed and Predicted Pollutographs

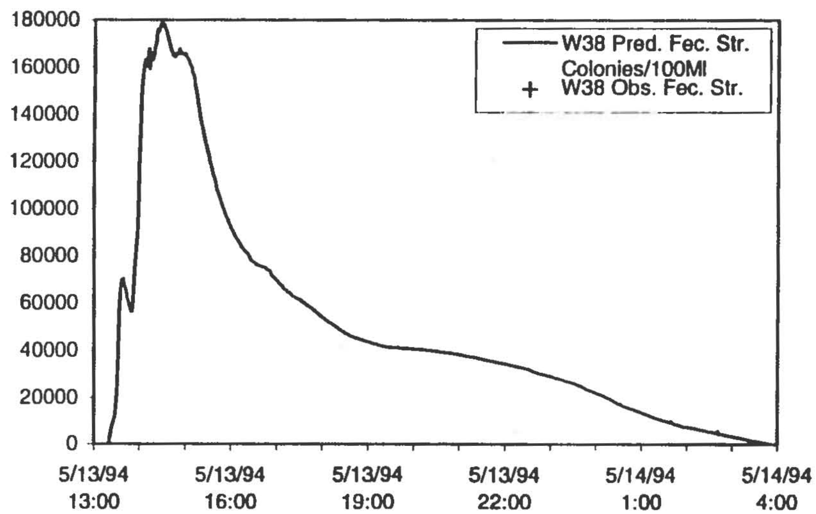


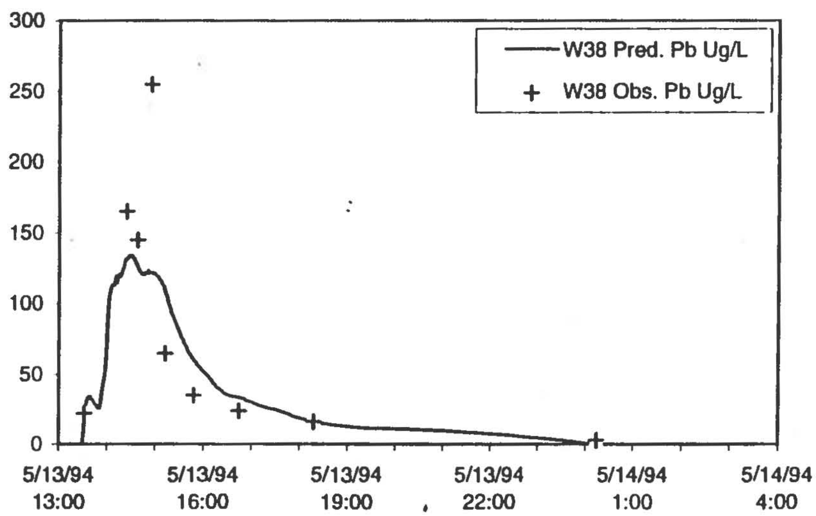
Appendix C
Observed and Predicted Pollutographs



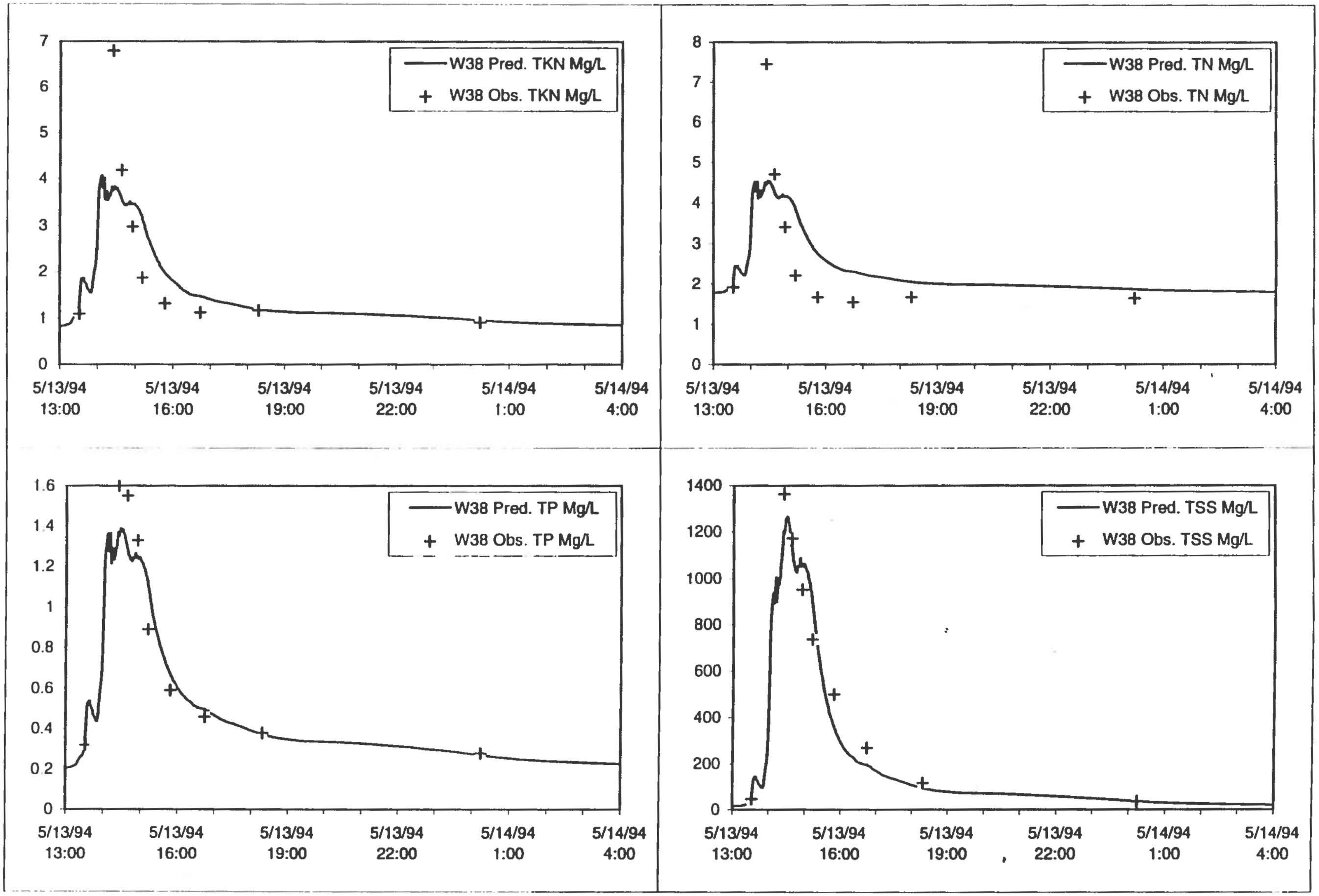

W38 Pred. BOD Mg/L
W38 Obs. BOD Mg/L
25
20
15
10
5
0
5/13/94 13:00
5/13/94 16:00
5/13/94 19:00
5/13/94 22:00
5/14/94 1:00
5/14/94 4:00


W38 Pred. COD Mg/L
W38 Obs. COD Mg/L
250
200
150
100
50
0
5/13/94 13:00
5/13/94 16:00
5/13/94 19:00
5/13/94 22:00
5/14/94 1:00
5/14/94 4:00

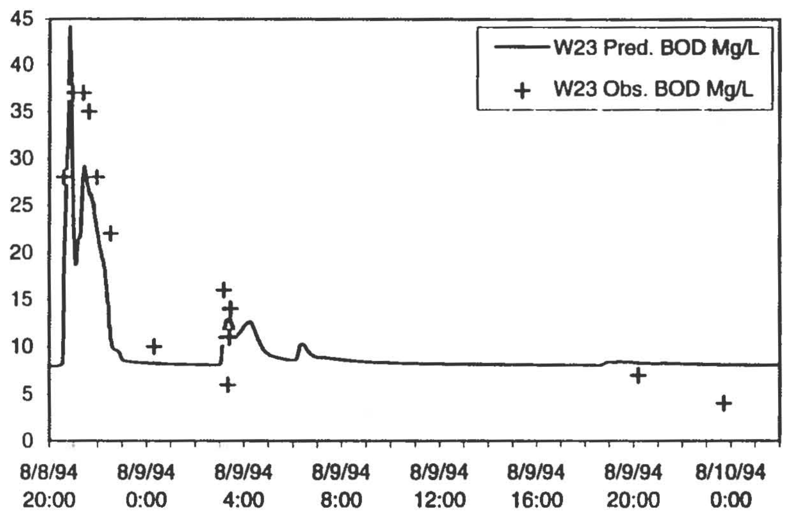

W38 Pred. Fec. Str. Colonies/100Ml
W38 Obs. Fec. Str.
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
5/13/94 13:00
5/13/94 16:00
5/13/94 19:00
5/13/94 22:00
5/14/94 1:00
5/14/94 4:00

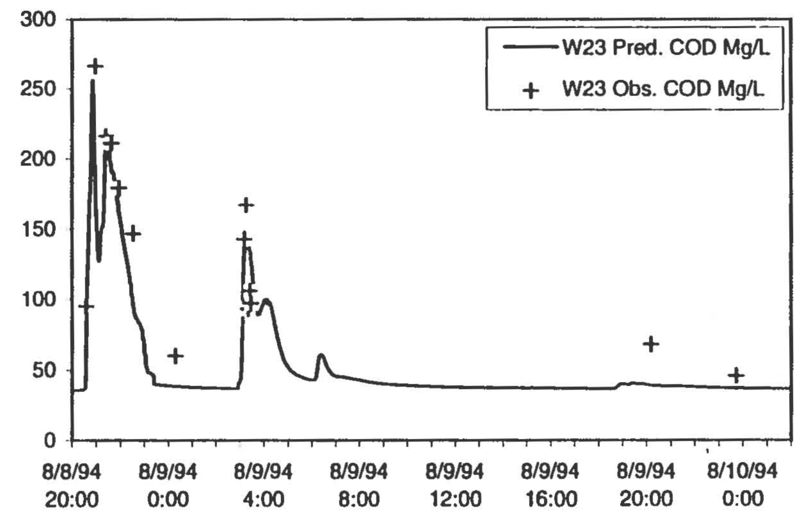

W38 Pred. Pb Ug/L
W38 Obs. Pb Ug/L
300
250
200
150
100
50
0
5/13/94 13:00
5/13/94 16:00
5/13/94 19:00
5/13/94 22:00
5/14/94 1:00
5/14/94 4:00

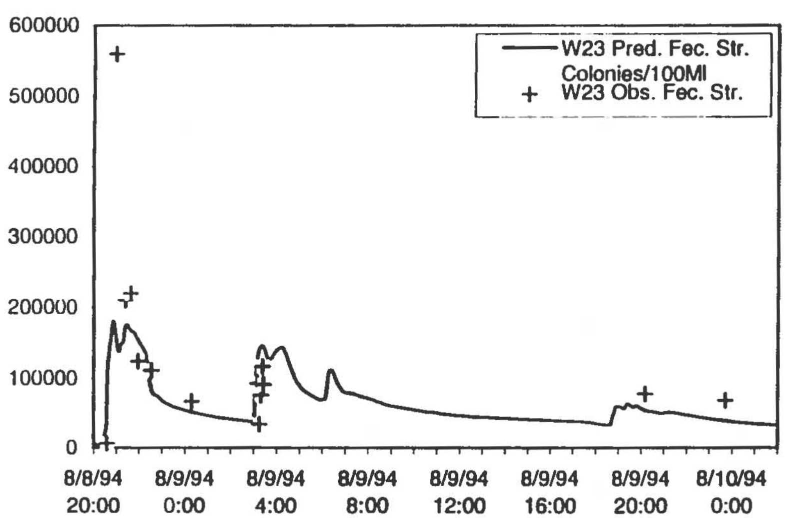
Appendix C
Observed and Predicted Pollutographs

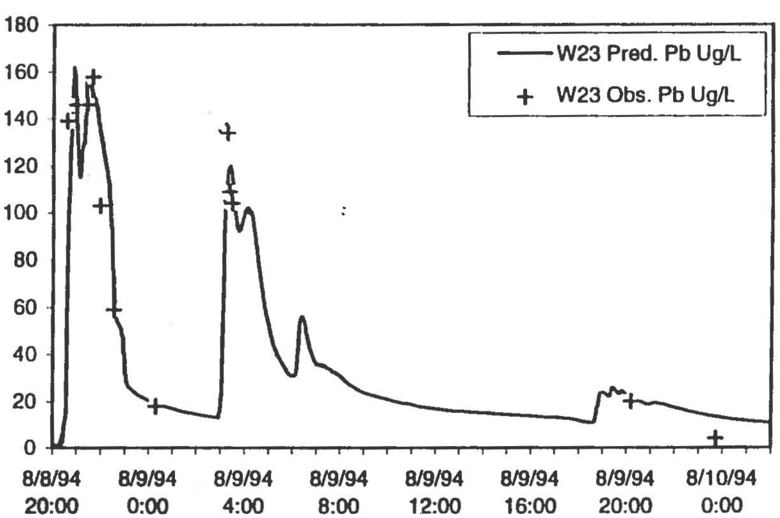


Appendix C
Observed and Predicted Pollutographs

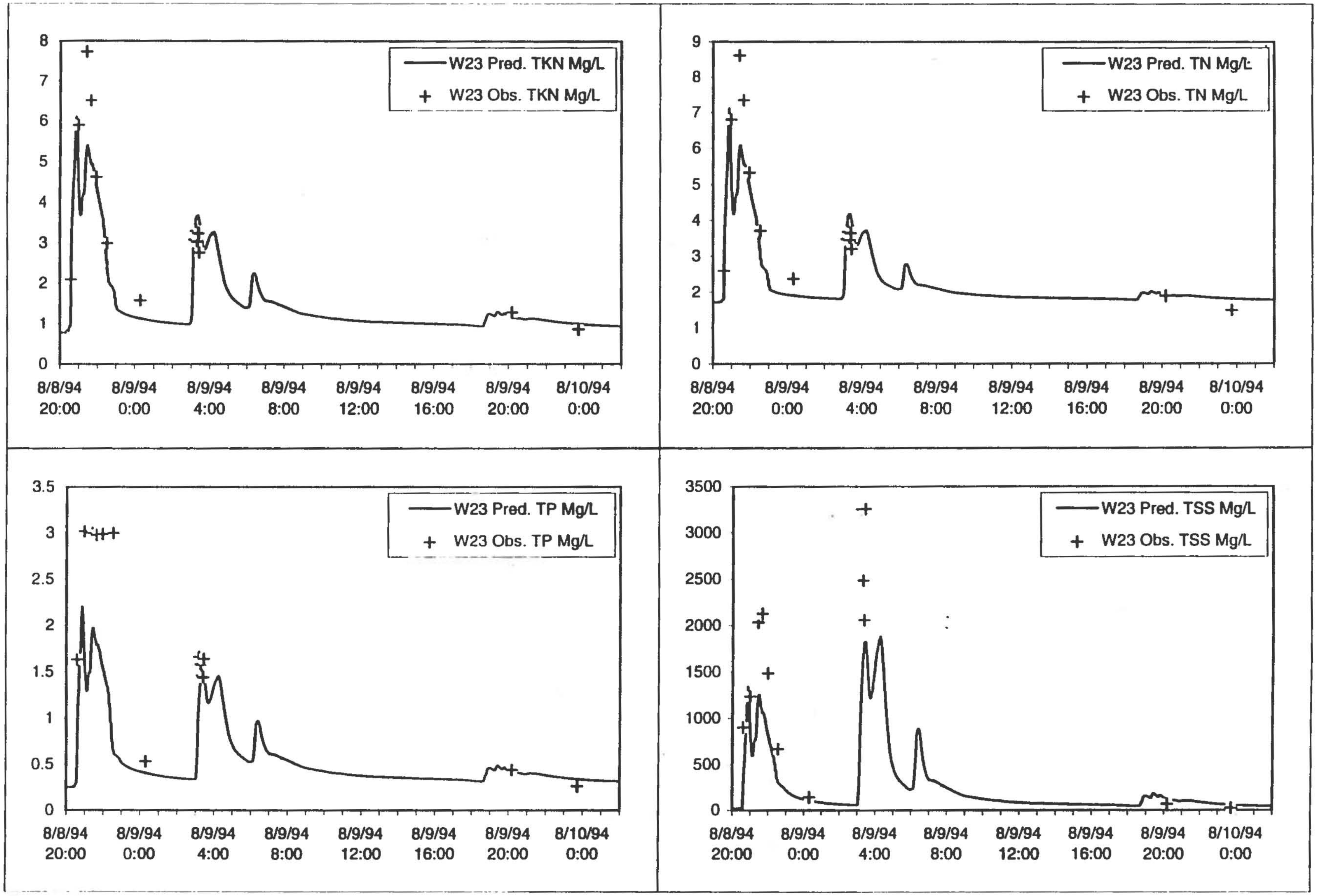




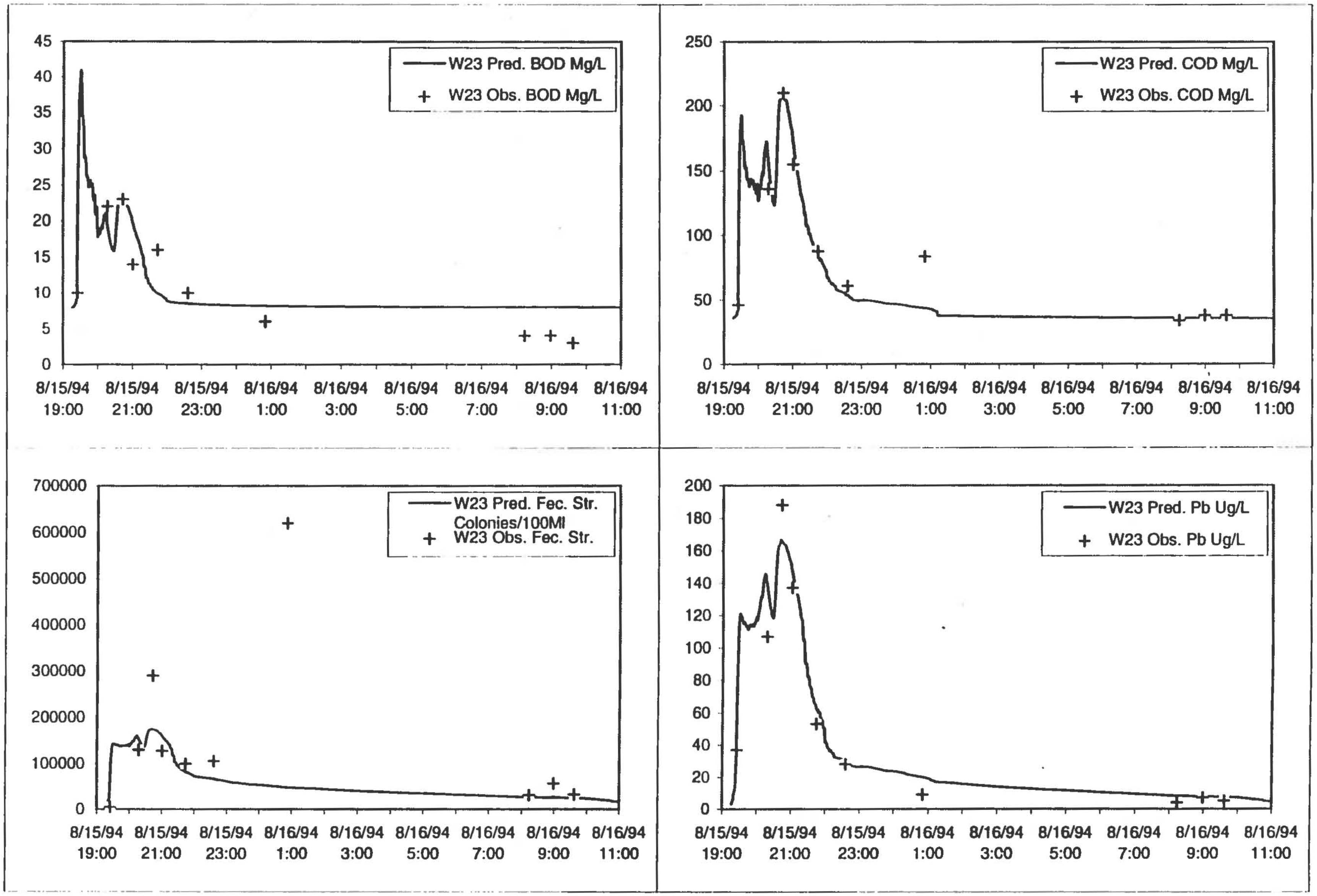




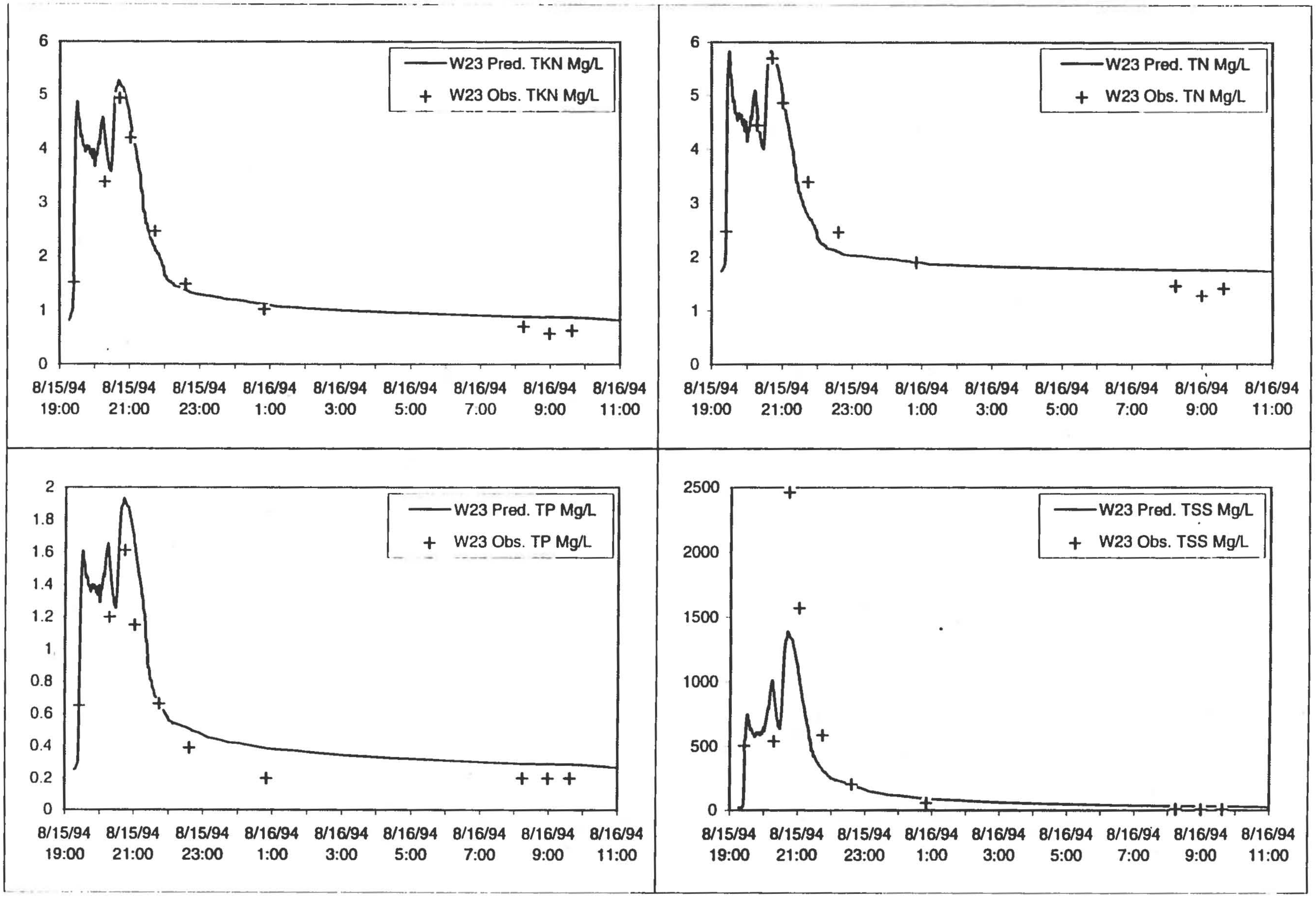
Appendix C
Observed and Predicted Pollutographs

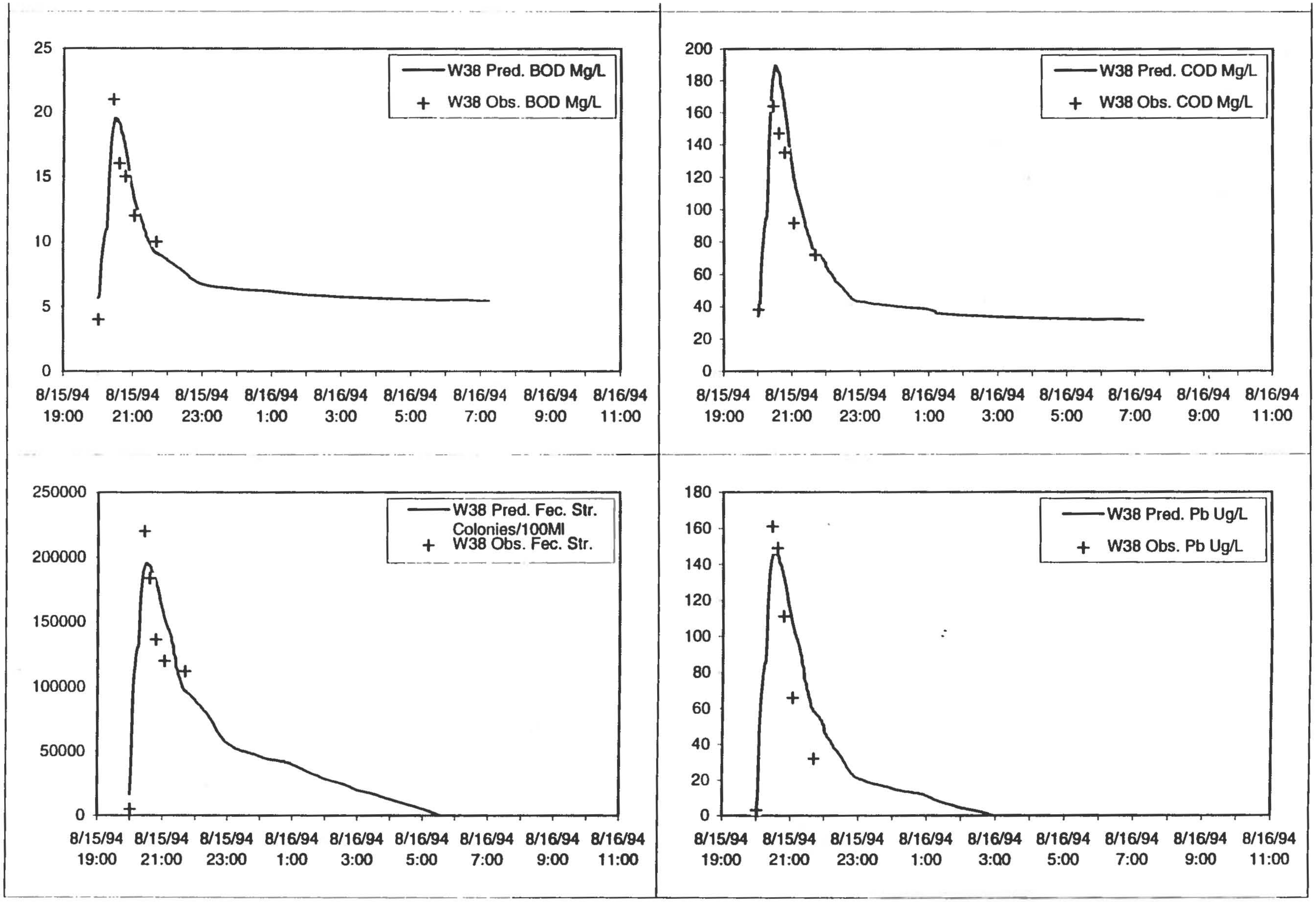


Appendix C
Observed and Predicted Pollutographs

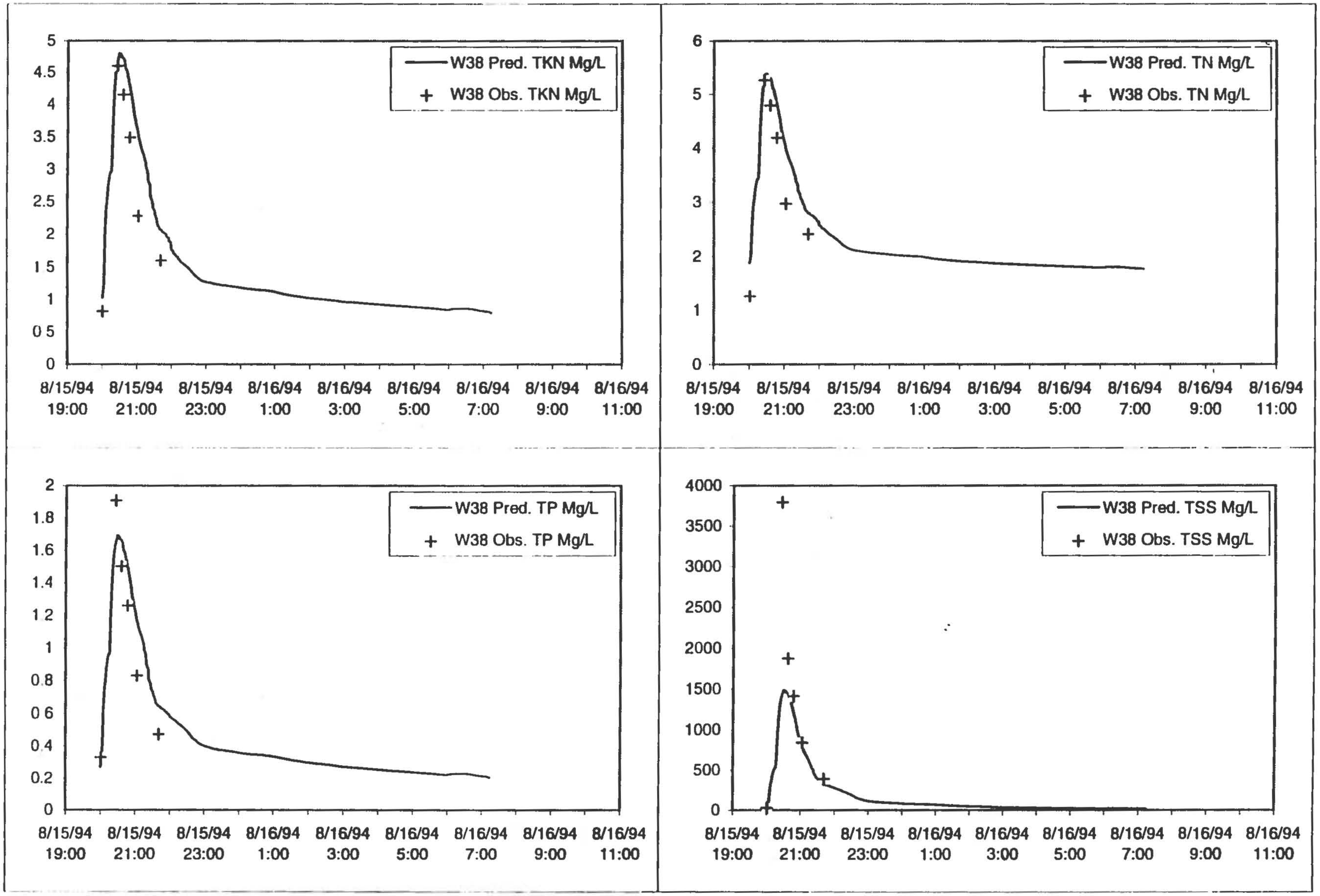


Appendix C
Observed and Predicted Pollutographs

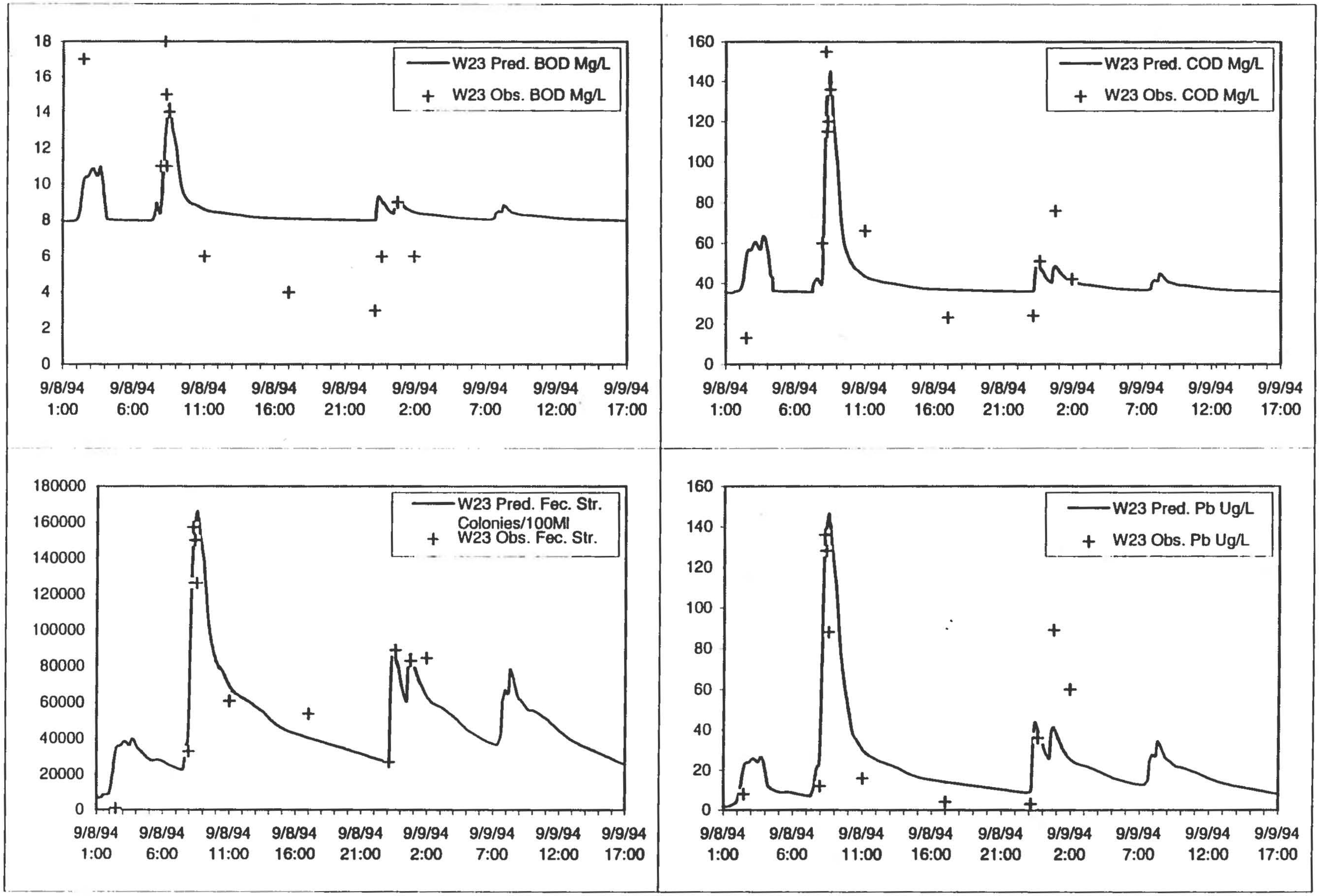



25
20
15
10
5
0
W38 Pred. BOD Mg/L
W38 Obs. BOD Mg/L
8/15/94 19:00
8/15/94 21:00
8/15/94 23:00
8/16/94 1:00
8/16/94 3:00
8/16/94 5:00
8/16/94 7:00
8/16/94 9:00
8/16/94 11:00
200
180
160
140
120
100
80
60
40
20
0
W38 Pred. COD Mg/L
W38 Obs. COD Mg/L
250000
200000
150000
100000
50000
0
W38 Pred. Fec. Str. Colonies/100Ml
W38 Obs. Fec. Str.
180
160
140
120
100
80
60
40
20
0
W38 Pred. Pb Ug/L
W38 Obs. Pb Ug/L

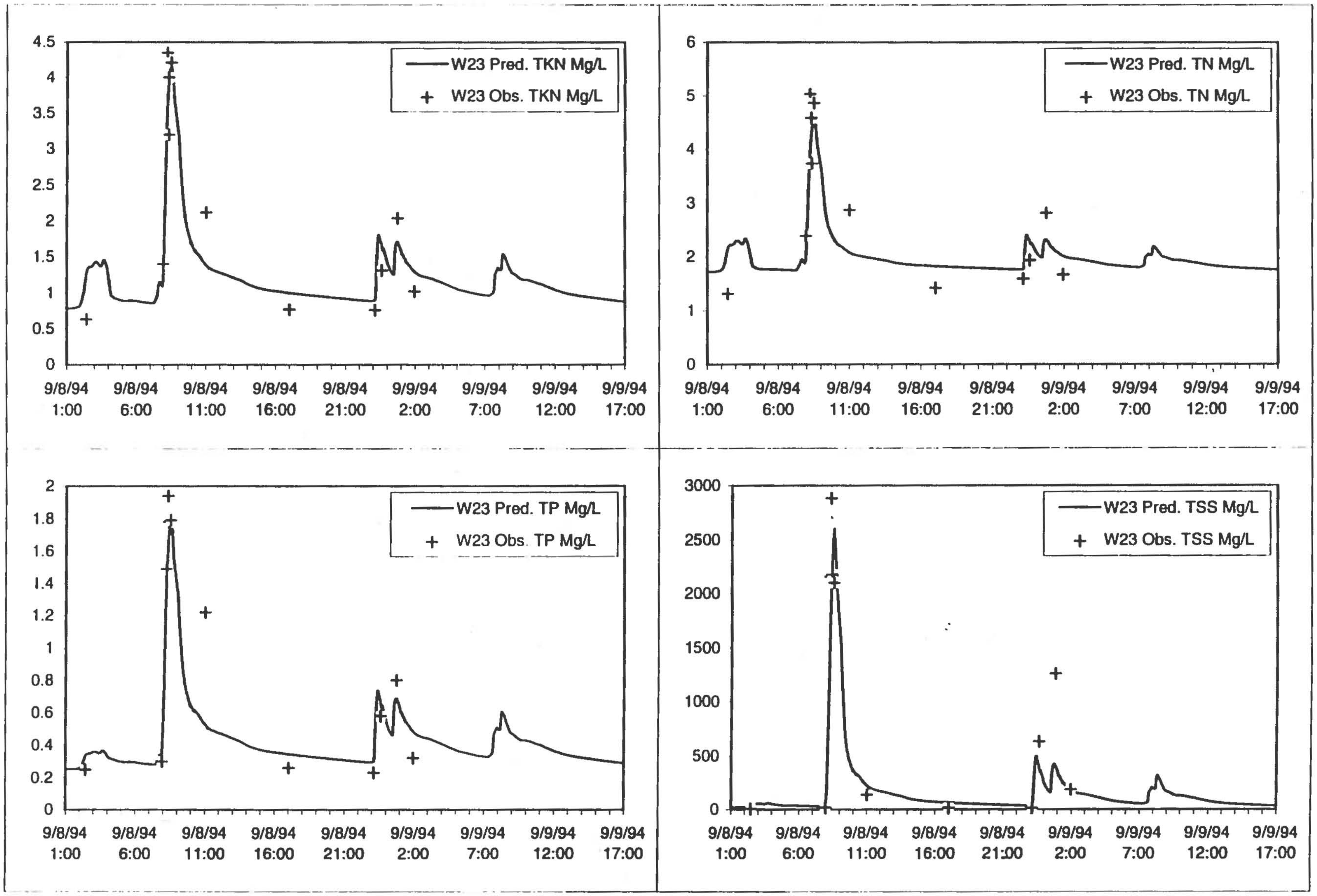
Appendix C
Observed and Predicted Pollutographs



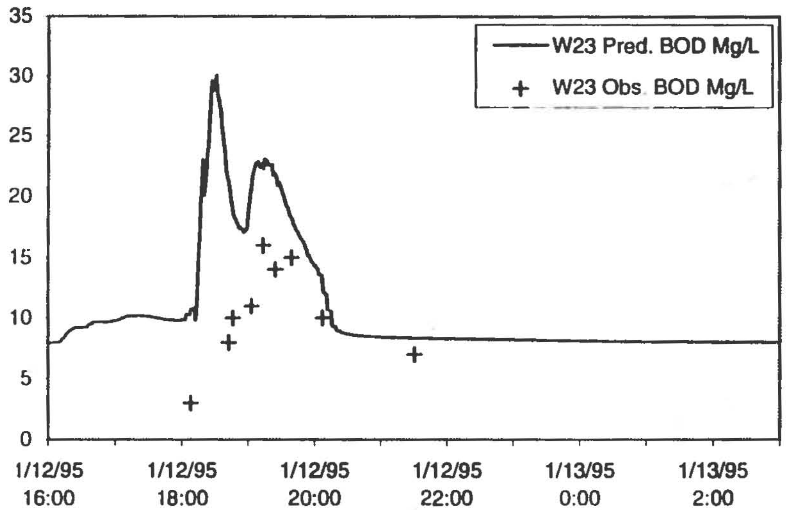
Appendix C
Observed and Predicted Pollutographs

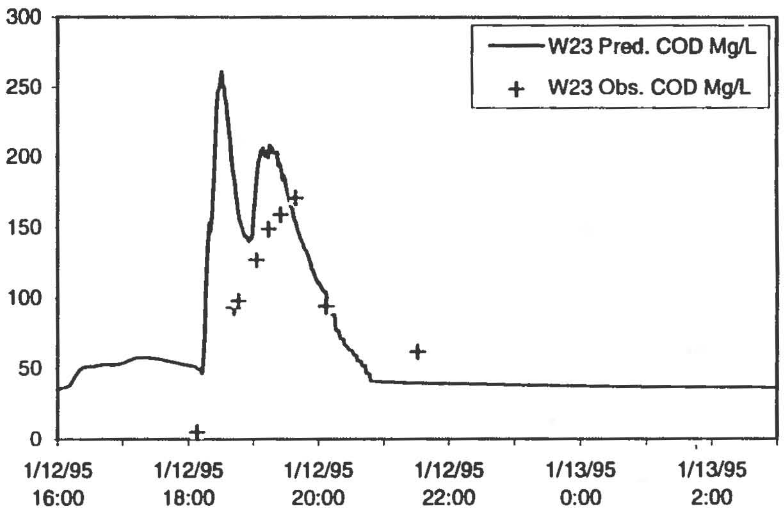


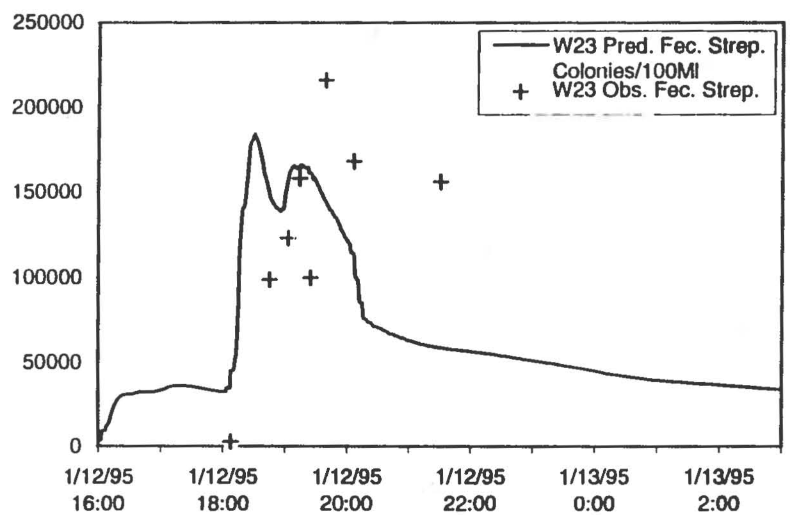
Appendix C
Observed and Predicted Pollutographs

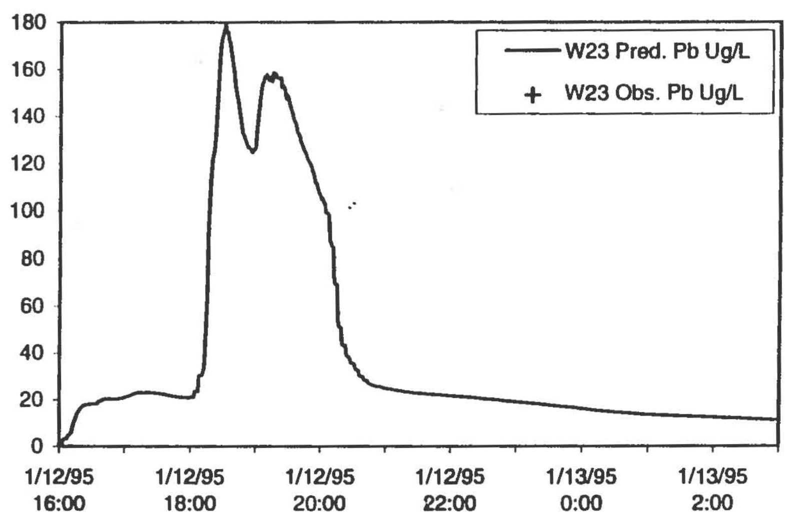


Appendix C
Observed and Predicted Pollutographs

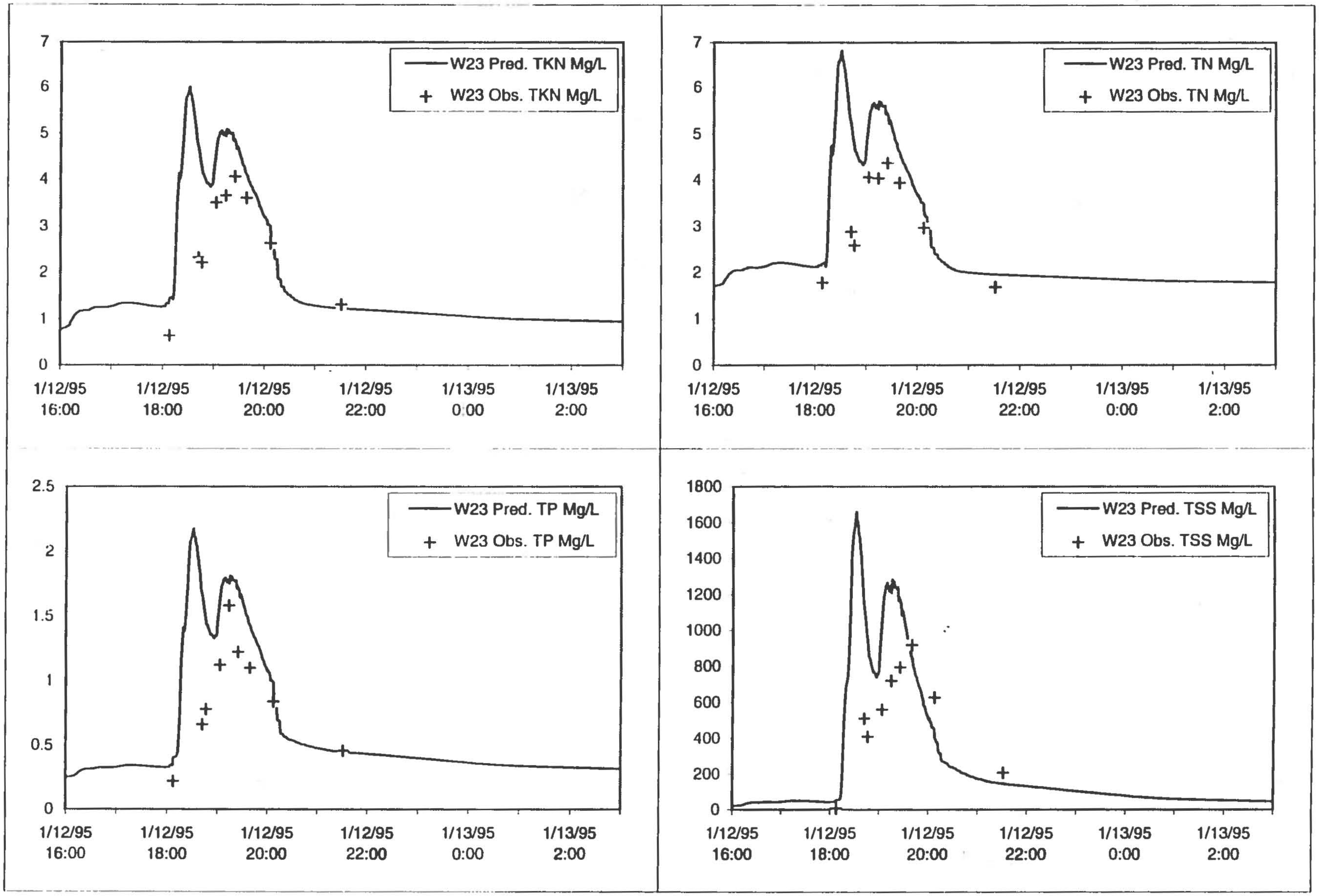




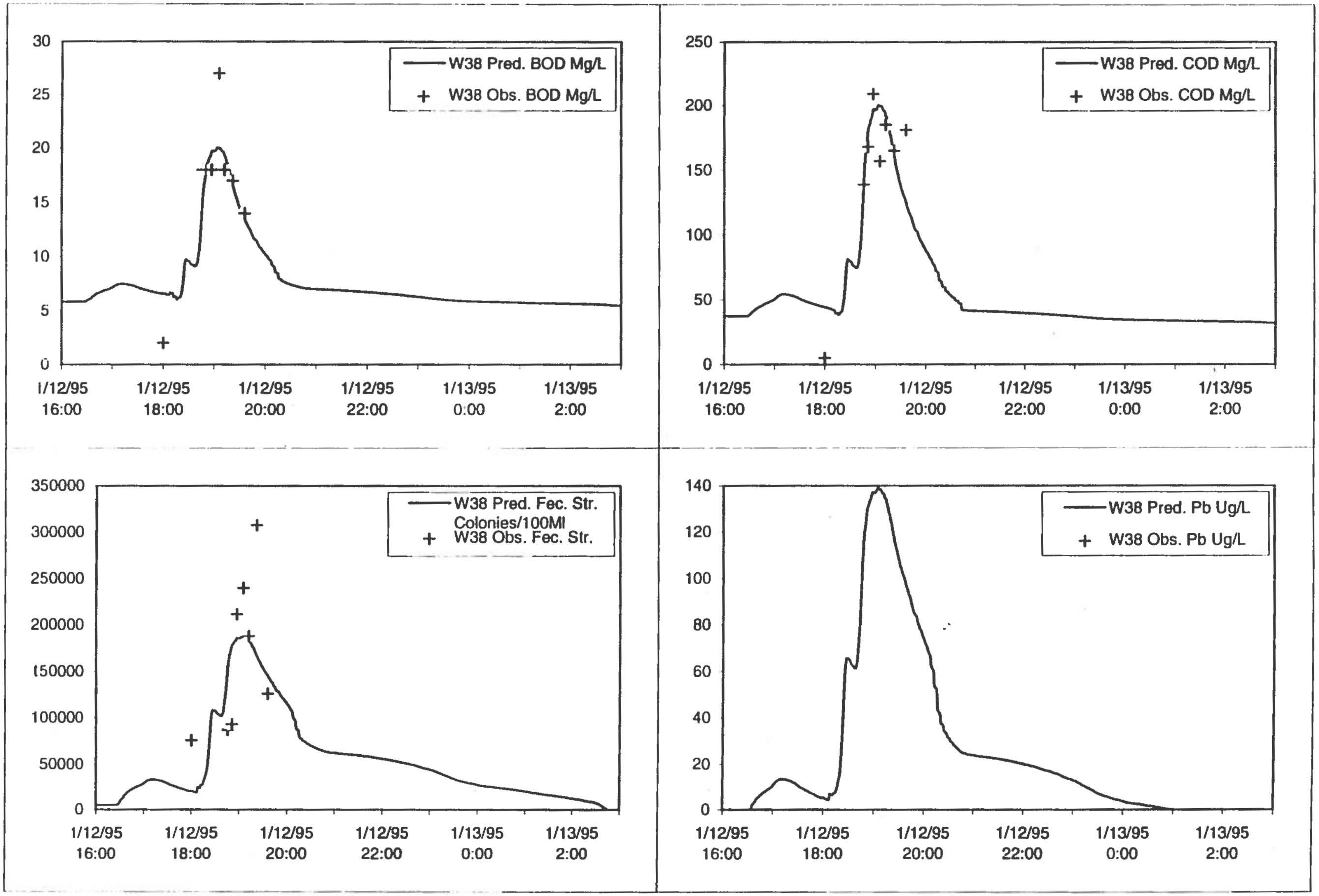




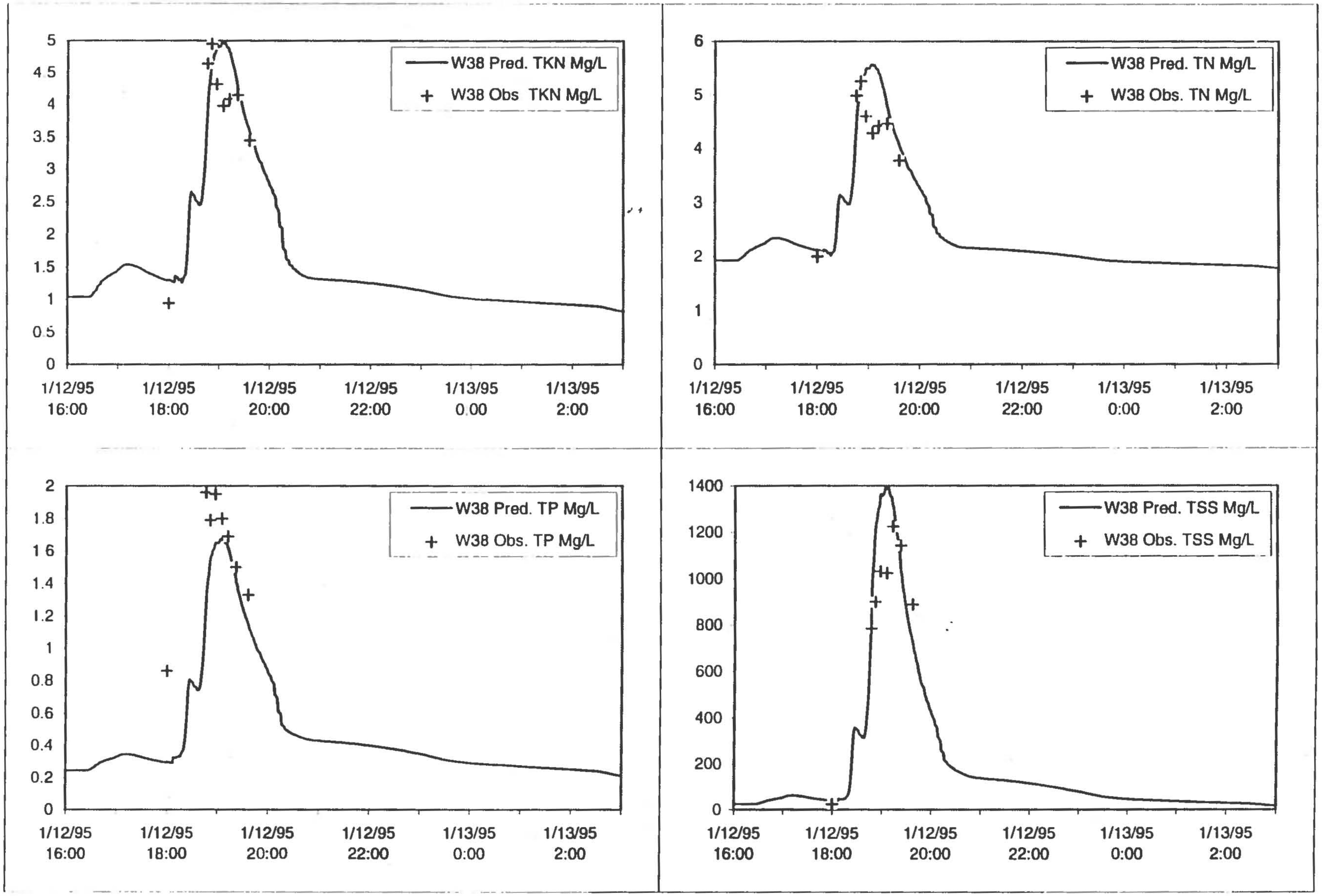
Appendix C
Observed and Predicted Pollutographs



Appendix C
Observed and Predicted Pollutographs



Appendix C
Observed and Predicted Pollutographs



Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
38th St.	10/20/93 02:20	1	1.001	1.001	1.001	1.834	225.15	224.70	302209	2260597	0.44	2307	43949
38th St.	10/20/93 02:46	2	1.001	1.007	1.007	1.834	191.90	191.46	636126	2260597	0.44	2997	43949
38th St.	10/20/93 03:22	3	0.523	1.022	1.022	1.834	108.12	107.67	934554	2260597	0.44	3951	43949
38th St.	10/20/93 05:01	4	0.439	1.448	1.451	1.834	76.25	75.80	1232685	2260597	0.44	6577	43949
38th St.	10/20/93 05:49	5	0.510	1.532	1.537	1.834	113.63	113.19	1533365	2260597	0.44	7850	43949
38th St.	10/20/93 07:00	6	0.213	1.661	1.661	1.834	61.37	60.92	1882989	2260597	0.44	9733	43949
38th St.	10/20/93 07:07	7	0.201	1.661	1.661	1.834	55.39	54.95	1907187	2260597	0.44	9918	43949
38th St.	10/29/93 14:27	1	0.179	0.179	0.179	0.372	1.22	0.72	581	186163	0.50	2610	25597
38th St.	10/29/93 16:23	2	0.175	0.353	0.356	0.372	6.01	5.51	23053	186163	0.50	6090	25597
38th St.	10/29/93 16:36	3	0.173	0.360	0.360	0.372	15.82	15.32	30535	186163	0.50	6480	25597
38th St.	10/29/93 16:45	4	0.138	0.360	0.360	0.372	20.98	20.48	40432	186163	0.50	6750	25597
38th St.	10/29/93 16:52	5	0.122	0.360	0.360	0.372	23.70	23.20	49783	186163	0.50	6960	25597
38th St.	10/29/93 16:59	6	0.111	0.360	0.360	0.372	25.46	24.96	59870	186163	0.50	7170	25597
38th St.	10/29/93 17:57	7	0.006	0.360	0.360	0.372	12.97	12.46	125058	186163	0.51	8921	25597
38th St.	10/29/93 18:45	8	0.000	0.360	0.360	0.372	7.30	6.79	151108	186163	0.51	10392	25597
38th St.	10/29/93 19:57	9	0.000	0.360	0.360	0.372	3.40	2.87	170204	186163	0.52	12636	25597
38th St.	10/29/93 20:05	10	0.000	0.360	0.360	0.372	3.05	2.52	171490	186163	0.53	12888	25597
38th St.	11/03/93 01:04	1	0.073	0.132	0.132	0.406	1.23	0.72	2468	201112	0.51	7818	39880
38th St.	11/03/93 04:57	2	0.101	0.393	0.393	0.406	15.82	15.30	74078	201112	0.51	14990	39880
38th St.	11/03/93 06:44	3	0.020	0.406	0.406	0.406	7.30	6.77	148576	201112	0.53	18342	39880
38th St.	11/03/93 08:05	4	0.000	0.406	0.406	0.406	4.33	3.79	173847	201112	0.54	20946	39880
38th St.	11/14/93 05:23	1	0.068	0.114	0.069	0.277	1.21	0.69	1170	141047	0.52	2176	27232
38th St.	11/14/93 07:59	2	0.156	0.310	0.264	0.277	7.91	7.39	49457	141047	0.52	7024	27232
38th St.	11/14/93 09:42	3	0.000	0.310	0.264	0.277	8.13	7.61	100849	141047	0.52	10229	27232
38th St.	11/16/93 07:55	1	0.119	0.395	0.119	0.173	1.22	0.62	973	22756	0.60	5436	33356
38th St.	11/16/93 09:45	2	0.019	0.415	0.138	0.173	1.46	0.86	7568	22756	0.60	9369	33356
38th St.	11/16/93 10:18	3	0.006	0.421	0.145	0.173	1.32	0.73	9161	22756	0.60	10549	33356
38th St.	11/16/93 10:41	4	0.006	0.421	0.145	0.173	1.21	0.62	10085	22756	0.60	11372	33356
38th St.	11/16/93 11:07	5	0.006	0.421	0.149	0.173	1.22	0.62	11010	22756	0.60	12301	33356
38th St.	11/16/93 13:49	6	0.000	0.449	0.173	0.173	1.21	0.62	15092	22756	0.60	18095	33356

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
38th St.	12/13/93 00:50	1	0.125	0.125	0.129	0.220	1.54	0.64	1080	38029	0.89	5519	41363
38th St.	12/13/93 01:14	2	0.180	0.186	0.189	0.220	2.20	1.30	2333	38029	0.89	6805	41363
38th St.	12/17/93 08:44	1	0.021	0.021	0.021	0.055	1.22	0.39	750	2725	0.84	2709	8527
38th St.	12/17/93 09:42	2	0.013	0.034	0.034	0.055	1.12	0.28	2321	2725	0.84	5618	8527
38th St.	01/20/94 19:51	1	0.123	0.223	0.161	0.386	1.24	0.69	866	239160	0.55	3584	47701
38th St.	01/20/94 20:25	2	0.171	0.304	0.231	0.386	3.45	2.90	4550	239160	0.55	4702	47701
38th St.	01/20/94 21:03	3	0.177	0.346	0.272	0.386	10.67	10.13	22020	239160	0.55	5951	47701
38th St.	01/20/94 21:07	4	0.175	0.346	0.272	0.386	10.61	10.06	24441	239160	0.55	6083	47701
38th St.	01/20/94 22:32	5	0.066	0.372	0.298	0.386	19.99	19.44	95624	239160	0.55	8877	47701
38th St.	01/20/94 23:22	6	0.026	0.378	0.304	0.386	12.69	12.14	145063	239160	0.55	10521	47701
38th St.	01/21/94 12:23	7	0.000	0.459	0.386	0.386	1.32	0.76	234256	239160	0.57	36241	47701
38th St.	02/10/94 03:16	1	0.032	0.078	0.032	0.222	1.24	0.67	270	145120	0.57	374	53530
38th St.	02/10/94 11:09	2	0.000	0.078	0.032	0.222	2.36	1.79	89671	145120	0.57	16466	53530
38th St.	02/10/94 14:37	3	0.027	0.111	0.065	0.222	1.87	1.30	105535	145120	0.57	23542	53530
38th St.	02/22/94 08:57	1	0.263	1.055	1.009	1.015	61.80	61.25	901984	1199606	0.56	30286	60278
38th St.	02/22/94 09:21	2	0.172	1.062	1.015	1.015	49.73	49.16	983212	1199606	0.56	31095	60278
38th St.	02/22/94 09:42	3	0.134	1.062	1.015	1.015	36.37	35.80	1035470	1199606	0.57	31809	60278
38th St.	02/22/94 10:14	4	0.066	1.062	1.015	1.015	22.75	22.17	1089392	1199606	0.58	32912	60278
38th St.	02/22/94 11:21	5	0.000	1.062	1.015	1.015	8.69	8.09	1142565	1199606	0.60	35274	60278
38th St.	02/22/94 14:42	6	0.000	1.062	1.015	1.015	2.04	1.39	1186614	1199606	0.65	42785	60278
38th St.	02/22/94 14:43	7	0.000	1.062	1.015	1.015	2.04	1.39	1186697	1199606	0.65	42824	60278
38th St.	02/22/94 14:48	8	0.000	1.062	1.015	1.015	2.00	1.34	1187107	1199606	0.65	43020	60278
38th St.	02/28/94 23:07	1	0.086	0.220	0.220	0.564	1.22	0.71	10383	509101	0.51	21568	57073
38th St.	03/01/94 05:49	2	0.305	0.552	0.552	0.564	72.80	72.29	189673	509101	0.51	33797	57073
38th St.	03/01/94 06:52	3	0.067	0.558	0.558	0.564	23.40	22.90	389996	509101	0.51	35713	57073
38th St.	03/01/94 11:44	4	0.000	0.564	0.564	0.564	2.49	1.93	497756	509101	0.57	44765	57073
38th St.	03/08/94 23:27	1	0.369	0.369	0.402	0.754	1.29	0.83	233	1006117	0.46	1306	37432
38th St.	03/09/94 00:05	2	0.607	0.607	0.607	0.754	159.41	158.95	104534	1006117	0.46	2361	37432
38th St.	03/09/94 00:15	3	0.610	0.610	0.613	0.754	185.68	185.22	206890	1006117	0.46	2639	37432
38th St.	03/09/94 00:24	4	0.620	0.620	0.620	0.754	167.35	166.89	303169	1006117	0.46	2889	37432

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
38th St.	03/09/94 00:34	5	0.637	0.637	0.642	0.754	145.77	145.31	398953	1006117	0.46	3167	37432
38th St.	03/09/94 01:14	6	0.576	0.701	0.701	0.754	75.62	75.15	630291	1006117	0.46	4278	37432
38th St.	03/09/94 02:49	7	0.084	0.728	0.728	0.754	16.04	15.58	828299	1006117	0.46	6917	37432
38th St.	03/09/94 12:16	8	0.000	0.754	0.754	0.754	2.62	2.11	981656	1006117	0.52	23065	37432
38th St.	03/09/94 14:00	9	0.000	0.754	0.754	0.754	2.29	1.75	993857	1006117	0.54	26351	37432
38th St.	03/15/94 05:31	1	0.186	0.560	0.201	0.662	1.24	0.71	235	790616	0.54	1065	49270
38th St.	03/15/94 07:18	2	0.376	0.793	0.434	0.662	78.00	77.46	211561	790616	0.54	4519	49270
38th St.	03/15/94 08:14	3	0.156	0.856	0.513	0.662	37.10	36.56	399648	790616	0.54	6327	49270
38th St.	03/15/94 10:45	4	0.000	0.736	0.520	0.662	11.94	11.40	616145	790616	0.54	11201	49270
38th St.	03/16/94 00:44	5	0.000	0.690	0.662	0.662	1.21	0.44	788771	790616	0.77	41076	49270
38th St.	04/06/94 16:43	1	0.428	0.428	0.428	0.475	1.22	0.68	235	663504	0.54	1301	27299
38th St.	04/06/94 17:14	2	0.434	0.434	0.434	0.475	184.48	183.94	198743	663504	0.54	2309	27299
38th St.	04/06/94 17:28	3	0.448	0.448	0.448	0.475	121.81	121.27	325473	663504	0.54	2765	27299
38th St.	04/06/94 17:36	4	0.448	0.448	0.448	0.475	90.60	90.05	374984	663504	0.54	3026	27299
38th St.	04/06/94 17:56	5	0.459	0.459	0.459	0.475	48.09	47.54	452315	663504	0.55	3681	27299
38th St.	04/06/94 18:26	6	0.098	0.475	0.475	0.475	36.69	36.14	524111	663504	0.55	4667	27299
38th St.	04/06/94 21:48	7	0.000	0.475	0.475	0.475	2.30	1.73	650298	663504	0.57	11441	27299
38th St.	04/29/94 01:58	1	0.443	0.523	0.647	1.262	0.88	0.40	630	1867428	0.48	4416	42399
38th St.	04/29/94 02:58	2	0.823	0.927	0.887	1.262	385.28	384.80	734171	1867428	0.48	6147	42399
38th St.	04/29/94 03:58	3	0.404	0.927	0.887	1.262	37.51	37.03	1188528	1867428	0.48	7879	42399
38th St.	04/29/94 04:58	4	0.015	0.942	0.934	1.262	13.37	12.89	1263489	1867428	0.48	9610	42399
38th St.	04/29/94 05:58	5	0.236	1.163	1.123	1.262	78.50	78.02	1408273	1867428	0.48	11342	42399
38th St.	04/29/94 06:58	6	0.287	1.229	1.198	1.262	27.46	26.98	1583986	1867428	0.49	13085	42399
38th St.	04/29/94 07:50	7	0.103	1.262	1.222	1.262	17.55	17.05	1650763	1867428	0.49	14616	42399
38th St.	04/29/94 08:50	8	0.054	1.276	1.238	1.262	12.48	11.98	1702838	1867428	0.50	16406	42399
38th St.	04/29/94 09:50	9	0.020	1.282	1.242	1.262	9.87	9.37	1739727	1867428	0.51	18219	42399
38th St.	04/29/94 10:50	10	0.006	1.282	1.242	1.262	8.28	7.77	1769865	1867428	0.51	20058	42399
38th St.	04/29/94 11:50	11	0.000	1.282	1.242	1.262	7.72	7.20	1797044	1867428	0.52	21921	42399
38th St.	04/29/94 12:50	12	0.000	1.282	1.242	1.262	6.51	5.98	1820844	1867428	0.53	23809	42399
38th St.	05/13/94 13:32	1	0.585	0.611	0.585	1.453	2.42	2.04	371	2465842	0.38	1673	33826

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
38th St.	05/13/94 14:24	2	1.325	1.351	1.325	1.453	458.58	458.20	429695	2465842	0.38	2865	33826
38th St.	05/13/94 14:38	3	1.367	1.393	1.369	1.453	429.46	429.07	831404	2465842	0.38	3187	33826
38th St.	05/13/94 14:55	4	1.363	1.399	1.373	1.453	397.06	396.67	1235804	2465842	0.39	3581	33826
38th St.	05/13/94 15:12	5	1.089	1.399	1.373	1.453	328.52	328.12	1619685	2465842	0.39	3981	33826
38th St.	05/13/94 15:48	6	0.642	1.470	1.444	1.453	97.54	97.13	2010689	2465842	0.41	4844	33826
38th St.	05/13/94 16:44	7	0.080	1.479	1.453	1.453	39.39	38.97	2198481	2465842	0.42	6232	33826
38th St.	05/13/94 18:18	8	0.000	1.479	1.453	1.453	12.93	12.48	2325729	2465842	0.45	8684	33826
38th St.	05/14/94 00:14	9	0.000	1.479	1.453	1.453	2.44	1.89	2454974	2465842	0.55	19361	33826
38th St.	08/08/94 20:37	1	0.674	0.674	0.674	2.294	1.27	0.84	194	3751460	0.44	626	57492
38th St.	08/09/94 20:01	2	0.212	2.294	2.294	2.294	13.01	12.58	3637638	3751460	0.44	37270	57492
38th St.	08/15/94 20:01	1	0.934	0.934	0.946	1.105	1.24	0.83	83	1672034	0.41	49	29172
38th St.	08/15/94 20:26	2	1.037	1.037	1.037	1.105	434.66	434.25	252412	1672034	0.41	658	29172
38th St.	08/15/94 20:36	3	1.049	1.049	1.049	1.105	462.59	462.17	531409	1672034	0.41	903	29172
38th St.	08/15/94 20:47	4	1.060	1.060	1.060	1.105	366.46	366.03	802160	1672034	0.42	1180	29172
38th St.	08/15/94 21:03	5	1.060	1.060	1.060	1.105	196.43	195.99	1060654	1672034	0.44	1595	29172
38th St.	08/15/94 21:41	6	0.396	1.060	1.060	1.105	77.00	76.52	1339931	1672034	0.48	2645	29172
38th St.	08/22/94 08:56	1	0.157	0.242	0.170	0.210	1.46	1.09	832	124617	0.37	1598	13631
38th St.	08/22/94 09:29	2	0.009	0.242	0.170	0.210	16.09	15.72	26737	124617	0.37	2331	13631
38th St.	08/22/94 11:44	3	0.006	0.248	0.176	0.210	3.21	2.84	95518	124617	0.37	5328	13631
38th St.	08/22/94 14:26	4	0.000	0.282	0.210	0.210	2.01	1.64	112786	124617	0.37	8924	13631
38th St.	09/14/94 16:19	1	0.094	0.548	0.119	0.398	1.39	1.03	249	363166	0.36	689	21625
38th St.	09/14/94 18:58	2	0.221	0.795	0.366	0.398	45.79	45.43	142093	363166	0.36	4114	21625
38th St.	09/14/94 19:24	3	0.145	0.795	0.366	0.398	26.75	26.38	196410	363166	0.37	4681	21625
38th St.	09/14/94 20:18	4	0.000	0.795	0.366	0.398	15.14	14.76	255016	363166	0.38	5888	21625
38th St.	09/14/94 21:37	5	0.000	0.795	0.366	0.398	10.36	9.97	315375	363166	0.40	7724	21625
38th St.	10/07/94 19:59	1	0.253	0.253	0.253	3.766	1.52	1.23	465	6389543	0.28	1943	37051
38th St.	10/07/94 20:32	2	0.253	0.253	0.253	3.766	6.30	6.02	9500	6389543	0.28	2505	37051
38th St.	10/07/94 22:21	3	0.648	0.902	0.912	3.766	162.17	161.89	169411	6389543	0.28	4362	37051
38th St.	10/07/94 22:35	4	0.918	1.171	1.246	3.766	199.85	199.56	318746	6389543	0.28	4601	37051
38th St.	10/07/94 22:46	5	1.132	1.418	1.454	3.766	273.89	273.60	481760	6389543	0.28	4788	37051

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
38th St.	10/07/94 22:54	6	1.273	1.571	1.626	3.766	301.87	301.58	621727	6389543	0.28	4925	37051
38th St.	10/15/94 07:45	1	0.040	0.732	0.732	0.847	8.46	8.10	448282	571476	0.35	15079	39764
38th St.	10/16/94 04:25	1	0.094	0.940	0.093	0.433	1.44	0.98	606	223412	0.46	1529	53204
38th St.	10/16/94 14:19	2	0.120	1.113	0.267	0.433	1.61	1.15	78089	223412	0.46	17745	53204
38th St.	10/16/94 22:26	3	0.006	1.161	0.314	0.433	1.24	0.78	191413	223412	0.46	31040	53204
38th St.	10/17/94 00:38	4	0.092	1.253	0.406	0.433	1.47	1.02	196078	223412	0.46	34644	53204
38th St.	10/17/94 02:50	5	0.000	1.253	0.406	0.433	1.48	1.03	206098	223412	0.46	38247	53204
38th St.	10/18/94 15:23	1	0.832	1.338	0.879	0.992	390.84	390.41	409618	1775128	0.43	4831	39401
38th St.	10/18/94 15:40	2	0.846	1.352	0.892	0.992	366.77	366.33	811307	1775128	0.44	5269	39401
38th St.	10/18/94 16:07	3	0.868	1.374	0.918	0.992	141.05	140.60	1203126	1775128	0.45	5987	39401
38th St.	10/18/94 19:02	4	0.000	1.433	0.986	0.992	19.26	18.71	1677362	1775128	0.55	11265	39401
38th St.	11/05/94 01:10	1	1.056	1.109	1.065	1.136	375.73	375.23	424238	1966239	0.50	2074	37087
38th St.	11/05/94 01:25	2	1.132	1.185	1.134	1.136	411.20	410.70	786511	1966239	0.50	2525	37087
38th St.	11/05/94 01:45	3	1.136	1.188	1.136	1.136	273.63	273.12	1203223	1966239	0.51	3133	37087
38th St.	11/05/94 02:22	4	0.804	1.188	1.136	1.136	97.68	97.15	1572911	1966239	0.53	4283	37087
38th St.	11/05/94 02:26	5	0.750	1.188	1.136	1.136	88.48	87.96	1594935	1966239	0.53	4410	37087
38th St.	11/05/94 13:16	6	0.000	1.188	1.136	1.136	1.05	0.27	1965211	1966239	0.79	30002	37087
38th St.	01/12/95 18:00	1	0.109	0.110	0.110	0.871	1.91	1.41	12393	1409165	0.50	2820	37016
38th St.	01/12/95 18:46	2	0.765	0.864	0.864	0.871	190.59	190.09	101801	1409165	0.50	4200	37016
38th St.	01/12/95 18:51	3	0.765	0.864	0.864	0.871	316.25	315.75	183031	1409165	0.50	4350	37016
38th St.	01/12/95 18:57	4	0.765	0.864	0.864	0.871	368.02	367.52	306566	1409165	0.50	4530	37016
38th St.	01/12/95 19:05	5	0.765	0.864	0.864	0.871	379.03	378.53	485498	1409165	0.50	4770	37016
38th St.	01/12/95 19:12	6	0.765	0.864	0.864	0.871	350.09	349.57	639720	1409165	0.52	4986	37016
38th St.	01/12/95 19:22	7	0.765	0.864	0.864	0.871	247.94	247.39	820064	1409165	0.55	5306	37016
38th St.	01/12/95 19:36	8	0.765	0.864	0.864	0.871	151.66	151.08	980233	1409165	0.58	5780	37016
23rd St.	09/26/93 14:37	1	0.079	0.084	0.084	0.084	2.05	1.74	1557	24731	0.31	3407	8667

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Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	10/20/93 01:06	1	0.272	0.272	0.305	1.883	4.67	4.13	486	4751003	0.54	1937	66650
23rd St.	10/20/93 02:05	2	0.935	0.935	0.953	1.883	304.84	304.30	591295	4751003	0.54	3841	66650
23rd St.	10/20/93 02:30	3	1.000	1.000	1.001	1.883	350.21	349.67	1190203	4751003	0.54	4648	66650
23rd St.	10/20/93 03:07	4	0.741	1.013	1.013	1.883	200.46	199.92	1788074	4751003	0.54	5843	66650
23rd St.	10/20/93 04:37	5	0.359	1.364	1.372	1.883	217.73	217.20	2390089	4751003	0.54	8748	66650
23rd St.	10/20/93 05:19	6	0.495	1.508	1.513	1.883	202.76	202.23	2984269	4751003	0.54	10104	66650
23rd St.	10/20/93 06:19	7	0.567	1.657	1.666	1.883	184.75	184.21	3595925	4751003	0.54	12040	66650
23rd St.	10/20/93 08:01	8	0.090	1.716	1.716	1.883	51.44	50.90	4182950	4751003	0.54	15333	66650
23rd St.	10/29/93 13:53	1	0.084	0.084	0.086	0.362	2.66	1.82	338	515291	0.84	653	44514
23rd St.	10/29/93 15:29	2	0.267	0.302	0.305	0.362	28.44	27.60	84902	515291	0.84	5474	44514
23rd St.	10/29/93 16:16	3	0.196	0.352	0.352	0.362	41.77	40.93	184385	515291	0.84	7834	44514
23rd St.	10/29/93 17:13	4	0.095	0.355	0.355	0.362	23.00	22.16	282891	515291	0.84	10697	44514
23rd St.	10/29/93 18:11	5	0.004	0.355	0.355	0.362	22.69	21.84	379865	515291	0.85	13632	44514
23rd St.	10/29/93 18:26	6	0.001	0.355	0.355	0.362	19.56	18.70	397931	515291	0.86	14403	44514
23rd St.	11/03/93 00:09	1	0.045	0.090	0.091	0.424	2.76	1.98	7960	645751	0.78	10657	66163
23rd St.	11/03/93 03:18	2	0.131	0.290	0.290	0.424	18.35	17.57	170239	645751	0.78	19491	66163
23rd St.	11/03/93 05:12	3	0.133	0.423	0.423	0.424	40.44	39.65	367732	645751	0.79	24831	66163
23rd St.	11/03/93 07:48	4	0.000	0.424	0.424	0.424	10.23	9.38	559794	645751	0.85	32522	66163
23rd St.	11/03/93 10:42	5	0.000	0.424	0.424	0.424	4.62	3.70	619991	645751	0.92	41761	66163
23rd St.	11/03/93 11:12	6	0.000	0.424	0.424	0.424	3.48	2.55	625138	645751	0.93	43424	66163
23rd St.	11/14/93 04:50	1	0.038	0.088	0.039	0.248	2.76	2.05	1428	427856	0.72	1893	37986
23rd St.	11/14/93 06:41	2	0.145	0.222	0.177	0.248	22.92	22.21	65506	427856	0.72	6668	37986
23rd St.	11/14/93 07:17	3	0.182	0.285	0.235	0.248	43.91	43.19	165291	427856	0.72	8217	37986
23rd St.	11/14/93 08:20	4	0.088	0.285	0.235	0.248	16.18	15.47	262788	427856	0.72	10927	37986
23rd St.	11/14/93 10:36	5	0.000	0.285	0.235	0.248	9.69	8.98	356610	427856	0.72	16778	37986
23rd St.	11/16/93 06:59	1	0.068	0.324	0.074	0.175	2.84	2.05	1236	140339	0.79	5655	51489
23rd St.	11/16/93 08:52	2	0.075	0.396	0.140	0.175	8.32	7.53	47088	140339	0.79	11025	51489
23rd St.	11/16/93 09:32	3	0.032	0.390	0.142	0.175	9.25	8.46	64589	140339	0.79	12925	51489
23rd St.	11/16/93 10:11	4	0.012	0.400	0.152	0.175	7.45	6.64	82311	140339	0.81	14796	51489
23rd St.	11/16/93 11:58	5	0.017	0.417	0.169	0.175	3.98	3.13	112311	140339	0.85	20124	51489

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Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	12/13/93 00:23	1	0.090	0.090	0.090	0.206	4.23	3.23	3383	165020	1.00	3836	42305
23rd St.	12/13/93 01:31	2	0.189	0.197	0.200	0.206	17.19	16.20	28739	165020	1.00	7912	42305
23rd St.	12/13/93 01:51	3	0.164	0.206	0.206	0.206	24.29	23.29	52238	165020	1.00	9111	42305
23rd St.	12/13/93 02:53	4	0.081	0.206	0.206	0.206	8.35	7.35	100210	165020	1.01	12839	42305
23rd St.	12/13/93 04:20	5	0.000	0.206	0.206	0.206	6.27	5.25	133747	165020	1.01	18109	42305
23rd St.	12/13/93 08:45	6	0.000	0.206	0.206	0.206	1.40	0.36	163935	165020	1.04	34450	42305
23rd St.	01/13/94 02:47	1	0.090	0.090	0.102	0.180	2.94	2.08	471	182274	0.85	5841	41760
23rd St.	01/13/94 03:25	2	0.168	0.168	0.168	0.180	19.39	18.53	27716	182274	0.85	7788	41760
23rd St.	01/13/94 03:58	3	0.174	0.174	0.174	0.180	20.14	19.27	76436	182274	0.88	9497	41760
23rd St.	01/13/94 04:19	4	0.169	0.174	0.174	0.180	12.72	11.82	95301	182274	0.90	10619	41760
23rd St.	01/13/94 05:11	5	0.025	0.174	0.174	0.180	9.44	8.49	123733	182274	0.95	13510	41760
23rd St.	01/13/94 05:26	6	0.006	0.174	0.174	0.180	8.45	7.49	130922	182274	0.97	14375	41760
23rd St.	01/20/94 18:34	1	0.049	0.125	0.060	0.389	2.80	1.49	3019	626591	1.32	14833	126241
23rd St.	01/20/94 19:36	2	0.099	0.187	0.123	0.389	6.10	4.79	10945	626591	1.32	19725	126241
23rd St.	01/20/94 20:03	3	0.147	0.238	0.181	0.389	20.56	19.24	26784	626591	1.32	21855	126241
23rd St.	01/20/94 21:35	4	0.174	0.358	0.293	0.389	28.51	27.19	214298	626591	1.32	29114	126241
23rd St.	01/20/94 22:45	5	0.029	0.358	0.293	0.389	23.92	22.60	318735	626591	1.32	34637	126241
23rd St.	01/20/94 23:57	6	0.003	0.361	0.297	0.389	18.52	17.21	412885	626591	1.32	40318	126241
23rd St.	01/21/94 11:50	7	0.000	0.452	0.388	0.389	2.79	1.44	610701	626591	1.36	96888	126241
23rd St.	01/21/94 13:08	8	0.000	0.452	0.388	0.389	2.85	1.48	616380	626591	1.37	103257	126241
23rd St.	01/21/94 13:32	9	0.000	0.452	0.388	0.389	2.81	1.44	618504	626591	1.37	105228	126241
23rd St.	01/24/94 13:25	1	0.000	0.414	0.414	0.483	6.82	5.80	384801	577305	1.02	71184	136869
23rd St.	01/24/94 13:55	2	0.000	0.414	0.414	0.483	6.31	5.29	394809	577305	1.02	73022	136869
23rd St.	01/24/94 14:54	3	0.000	0.414	0.414	0.483	5.39	4.37	411947	577305	1.02	76636	136869
23rd St.	02/10/94 02:52	1	0.034	0.071	0.034	0.240	3.71	2.92	508	495763	0.79	2077	86652
23rd St.	02/10/94 03:26	2	0.034	0.071	0.034	0.240	29.30	28.51	24111	495763	0.79	3683	86652
23rd St.	02/10/94 06:00	3	0.000	0.071	0.034	0.240	8.42	7.63	136071	495763	0.79	10955	86652
23rd St.	02/10/94 09:31	4	0.000	0.071	0.034	0.240	7.35	6.56	246202	495763	0.79	20918	86652
23rd St.	02/10/94 14:47	5	0.034	0.120	0.083	0.240	8.58	7.76	372891	495763	0.82	35908	86652
23rd St.	02/22/94 09:04	1	0.261	1.119	1.079	1.081	98.05	97.12	2164818	2717805	0.93	50951	109941

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	02/22/94 09:16	2	0.212	1.121	1.081	1.081	86.27	85.33	2228892	2717805	0.94	51626	109941
23rd St.	02/22/94 09:29	3	0.156	1.121	1.081	1.081	74.27	73.31	2290196	2717805	0.95	52367	109941
23rd St.	02/22/94 09:43	4	0.131	1.121	1.081	1.081	64.58	63.61	2347305	2717805	0.97	53173	109941
23rd St.	02/22/94 10:01	5	0.091	1.121	1.081	1.081	51.95	50.97	2407921	2717805	0.98	54226	109941
23rd St.	02/22/94 10:24	6	0.009	1.121	1.081	1.081	39.64	38.64	2468683	2717805	1.00	55595	109941
23rd St.	02/22/94 15:21	7	0.000	1.121	1.081	1.081	4.95	3.69	2686235	2717805	1.26	75747	109941
23rd St.	02/28/94 16:38	1	0.053	0.053	0.053	0.581	2.85	1.93	7375	1183029	0.92	34352	128485
23rd St.	02/28/94 20:50	2	0.013	0.114	0.114	0.581	2.81	1.89	56254	1183029	0.92	48248	128485
23rd St.	02/28/94 21:18	3	0.043	0.144	0.148	0.581	2.81	1.89	59334	1183029	0.92	49791	128485
23rd St.	03/01/94 05:11	4	0.307	0.558	0.558	0.581	199.30	198.38	414049	1183029	0.92	75873	128485
23rd St.	03/01/94 06:40	5	0.287	0.576	0.576	0.581	67.21	66.29	847036	1183029	0.92	80780	128485
23rd St.	03/01/94 08:25	6	0.003	0.578	0.579	0.581	15.71	14.79	1053675	1183029	0.92	86570	128485
23rd St.	03/01/94 10:19	7	0.004	0.579	0.579	0.581	7.23	6.31	1118477	1183029	0.92	92856	128485
23rd St.	03/01/94 11:12	8	0.000	0.579	0.579	0.581	6.96	6.04	1136401	1183029	0.92	95778	128485
23rd St.	03/01/94 12:12	9	0.001	0.581	0.581	0.581	4.52	3.54	1154053	1183029	0.98	99194	128485
23rd St.	03/08/94 23:17	1	0.218	0.220	0.236	0.732	2.52	1.65	356	1866164	0.88	7146	83576
23rd St.	03/08/94 23:39	2	0.476	0.477	0.499	0.732	261.64	260.76	179038	1866164	0.88	8303	83576
23rd St.	03/08/94 23:55	3	0.576	0.577	0.584	0.732	177.27	176.39	389171	1866164	0.88	9143	83576
23rd St.	03/09/94 00:30	4	0.612	0.613	0.615	0.732	227.26	226.38	765297	1866164	0.88	10983	83576
23rd St.	03/09/94 01:02	5	0.656	0.669	0.674	0.732	131.39	130.46	1112113	1866164	0.93	12721	83576
23rd St.	03/09/94 02:03	6	0.097	0.687	0.687	0.732	62.41	61.38	1476300	1866164	1.03	16317	83576
23rd St.	03/09/94 06:03	7	0.007	0.715	0.715	0.732	9.85	8.42	1791031	1866164	1.43	34061	83576
23rd St.	03/09/94 11:02	8	0.014	0.732	0.732	0.732	3.77	1.84	1860404	1866164	1.93	64191	83576
23rd St.	03/15/94 05:19	1	0.088	0.442	0.115	0.662	2.67	1.71	205	1590228	0.96	2592	102099
23rd St.	03/15/94 07:28	2	0.186	0.716	0.377	0.662	78.36	77.40	385539	1590228	0.96	10022	102099
23rd St.	03/15/94 09:25	3	0.077	0.701	0.450	0.662	34.59	33.63	788660	1590228	0.96	16762	102099
23rd St.	04/06/94 16:36	1	0.363	0.363	0.363	0.408	3.24	2.42	278	980264	0.83	545	47613
23rd St.	04/06/94 17:21	2	0.382	0.382	0.384	0.408	164.47	163.65	242326	980264	0.83	2772	47613
23rd St.	04/06/94 17:34	3	0.386	0.386	0.386	0.408	176.00	175.17	387564	980264	0.83	3417	47613
23rd St.	04/06/94 17:52	4	0.389	0.389	0.389	0.408	109.51	108.67	536531	980264	0.84	4318	47613

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	04/06/94 18:25	5	0.111	0.402	0.402	0.408	54.77	53.91	684649	980264	0.86	6001	47613
23rd St.	04/06/94 19:29	6	0.022	0.408	0.408	0.408	27.65	26.75	833118	980264	0.90	9373	47613
23rd St.	04/06/94 22:07	7	0.000	0.408	0.408	0.408	5.57	4.58	943166	980264	0.99	18314	47613
23rd St.	04/29/94 01:08	1	0.085	0.142	0.085	1.208	3.30	2.51	2461	3525188	0.80	5438	81523
23rd St.	04/29/94 02:10	2	0.782	0.867	0.811	1.208	606.05	605.25	415204	3525188	0.80	8395	81523
23rd St.	04/29/94 02:26	3	0.774	0.870	0.814	1.208	223.02	222.22	781226	3525188	0.80	9158	81523
23rd St.	04/29/94 02:49	4	0.772	0.871	0.814	1.208	454.72	453.92	1187945	3525188	0.80	10256	81523
23rd St.	04/29/94 03:04	5	0.733	0.871	0.814	1.208	379.67	378.88	1590134	3525188	0.80	10971	81523
23rd St.	04/29/94 10:00	6	0.027	1.253	1.196	1.208	17.66	16.87	3303156	3525188	0.80	30814	81523
23rd St.	04/29/94 14:10	7	0.000	1.253	1.196	1.208	7.19	6.39	3452841	3525188	0.80	42739	81523
23rd St.	05/13/94 13:16	1	0.388	0.419	0.388	1.388	3.93	2.95	246	4797372	0.98	3172	76480
23rd St.	05/13/94 14:18	2	1.169	1.200	1.189	1.388	955.37	954.39	814987	4797372	0.98	6814	76480
23rd St.	05/13/94 14:30	3	1.270	1.301	1.280	1.388	1114.28	1113.30	1596138	4797372	0.98	7519	76480
23rd St.	05/13/94 14:44	4	1.301	1.332	1.301	1.388	764.80	763.81	2395873	4797372	0.99	8345	76480
23rd St.	05/13/94 15:06	5	1.192	1.333	1.302	1.388	525.56	524.56	3198461	4797372	1.00	9655	76480
23rd St.	05/13/94 15:47	6	0.659	1.378	1.358	1.388	157.82	156.80	3978321	4797372	1.02	12134	76480
23rd St.	05/13/94 20:15	7	0.000	1.419	1.388	1.388	10.43	9.28	4672743	4797372	1.15	29537	76480
23rd St.	05/13/94 20:18	8	0.000	1.419	1.388	1.388	10.33	9.18	4674404	4797372	1.15	29744	76480
23rd St.	05/13/94 21:03	9	0.000	1.419	1.388	1.388	9.44	8.27	4698031	4797372	1.17	32874	76480
23rd St.	05/13/94 22:44	10	0.000	1.419	1.388	1.388	7.30	6.08	4741473	4797372	1.22	40113	76480
23rd St.	05/14/94 01:16	11	0.000	1.419	1.388	1.388	4.04	2.75	4781743	4797372	1.29	51566	76480
23rd St.	08/04/94 15:00	1	0.101	0.101	0.101	0.101	4.23	3.69	919	101599	0.54	3349	32665
23rd St.	08/04/94 17:41	2	0.000	0.101	0.101	0.101	2.80	2.26	79859	101599	0.54	8585	32665
23rd St.	08/08/94 20:35	1	0.498	0.498	0.548	2.841	3.61	3.16	228	11022079	0.45	895	81971
23rd St.	08/08/94 20:58	2	0.670	0.670	0.701	2.841	225.27	224.82	263301	11022079	0.45	1518	81971
23rd St.	08/08/94 21:24	3	0.754	0.754	0.754	2.841	354.47	354.02	569754	11022079	0.45	2223	81971
23rd St.	08/08/94 21:38	4	0.754	0.754	0.754	2.841	307.90	307.45	858350	11022079	0.45	2603	81971
23rd St.	08/08/94 21:57	5	0.754	0.754	0.754	2.841	211.28	210.83	1161295	11022079	0.45	3118	81971
23rd St.	08/08/94 22:32	6	0.257	0.754	0.754	2.841	98.69	98.24	1459379	11022079	0.45	4068	81971
23rd St.	08/09/94 00:18	7	0.000	0.754	0.754	2.841	20.38	19.93	1756539	11022079	0.45	6942	81971

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	08/09/94 03:11	8	0.464	1.218	1.317	2.841	757.67	757.22	2039876	11022079	0.45	11634	81971
23rd St.	08/09/94 03:16	9	0.673	1.428	1.428	2.841	1181.79	1181.34	2345962	11022079	0.45	11770	81971
23rd St.	08/09/94 03:20	10	0.747	1.502	1.502	2.841	1346.23	1345.78	2652071	11022079	0.45	11878	81971
23rd St.	08/09/94 03:24	11	0.815	1.570	1.570	2.841	1401.71	1401.26	2985139	11022079	0.45	11987	81971
23rd St.	08/09/94 03:27	12	0.815	1.570	1.603	2.841	1337.58	1337.12	3231515	11022079	0.45	12068	81971
23rd St.	08/09/94 20:11	13	0.184	2.835	2.835	2.841	24.22	23.70	10779132	11022079	0.52	39385	81971
23rd St.	08/09/94 23:43	14	0.000	2.835	2.836	2.841	7.05	6.24	10959343	11022079	0.81	47799	81971
23rd St.	08/15/94 19:25	1	0.339	0.339	0.358	0.938	11.25	10.63	749	2592281	0.62	373	66408
23rd St.	08/15/94 20:17	2	0.871	0.871	0.873	0.938	290.99	290.37	471879	2592281	0.62	2310	66408
23rd St.	08/15/94 20:43	3	0.895	0.895	0.900	0.938	527.84	527.21	984536	2592281	0.62	3279	66408
23rd St.	08/15/94 21:01	4	0.900	0.900	0.900	0.938	365.74	365.09	1481952	2592281	0.65	3965	66408
23rd St.	08/15/94 21:44	5	0.319	0.900	0.900	0.938	106.47	105.78	1967699	2592281	0.70	5701	66408
23rd St.	08/15/94 22:36	6	0.019	0.909	0.909	0.938	57.44	56.68	2200500	2592281	0.76	7981	66408
23rd St.	08/16/94 00:50	7	0.029	0.938	0.938	0.938	15.81	14.88	2431162	2592281	0.93	14771	66408
23rd St.	08/16/94 08:14	8	0.000	0.938	0.938	0.938	2.84	1.37	2582722	2592281	1.47	46687	66408
23rd St.	08/16/94 08:59	9	0.000	0.938	0.938	0.938	2.80	1.28	2586126	2592281	1.52	50730	66408
23rd St.	08/16/94 09:37	10	0.000	0.938	0.938	0.938	2.67	1:10	2588743	2592281	1.57	54259	66408
23rd St.	08/22/94 07:13	1	0.070	0.131	0.128	0.226	2.63	1.76	14240	332397	0.86	47427	96400
23rd St.	08/22/94 09:14	2	0.038	0.169	0.163	0.226	3.48	2.62	97392	332397	0.86	53685	96400
23rd St.	08/22/94 09:57	3	0.000	0.169	0.163	0.226	3.07	2.21	103014	332397	0.86	55909	96400
23rd St.	08/22/94 14:06	4	0.008	0.232	0.226	0.226	7.00	6.13	275809	332397	0.87	68805	96400
23rd St.	08/22/94 17:30	5	0.000	0.232	0.226	0.226	3.14	2.23	317465	332397	0.91	79744	96400
23rd St.	09/08/94 02:27	1	0.075	0.075	0.075	2.751	2.81	2.20	1279	9710839	0.61	5124	116667
23rd St.	09/08/94 07:57	2	0.739	0.814	0.855	2.751	3.01	2.40	45600	9710839	0.61	17202	116667
23rd St.	09/08/94 08:14	3	1.549	1.624	1.680	2.751	1136.24	1135.63	402352	9710839	0.61	17824	116667
23rd St.	09/08/94 08:19	4	1.654	1.729	1.784	2.751	1626.36	1625.75	838435	9710839	0.61	18007	116667
23rd St.	09/08/94 08:22	5	1.721	1.796	1.815	2.751	1859.20	1858.59	1160171	9710839	0.61	18117	116667
23rd St.	09/08/94 08:31	6	1.765	1.840	1.844	2.751	2308.77	2308.16	2315812	9710839	0.61	18446	116667
23rd St.	09/08/94 11:01	7	0.114	2.026	2.026	2.751	66.61	66.00	7042789	9710839	0.61	23936	116667
23rd St.	09/08/94 17:00	8	0.000	2.040	2.040	2.751	7.89	7.28	7579050	9710839	0.61	37076	116667

Appendix D: Rainfall and Flow Data for Water Quality Samples

Site	Date and Time	Sample Number	Total Rainfall 2 Hours	Total Rainfall 64 Hours	Cumulat. Rainfall Event	Total Rainfall Event	Stream Flowrate CFS	Instant. Runoff CFS	Cumulat. Runoff CF	Total Runoff CF	Instant. Baseflow CFS	Cumulat. Baseflow CF	Total Baseflow CF
23rd St.	09/08/94 23:08	9	0.037	2.077	2.077	2.751	2.76	2.15	7662781	9710839	0.61	50545	116667
23rd St.	09/08/94 23:36	10	0.368	2.408	2.408	2.751	159.77	159.16	7907617	9710839	0.61	51569	116667
23rd St.	09/09/94 00:45	11	0.463	2.504	2.504	2.751	172.87	172.26	8304045	9710839	0.61	54095	116667
23rd St.	09/09/94 01:56	12	0.047	2.504	2.504	2.751	47.69	47.08	8699124	9710839	0.61	56693	116667
23rd St.	10/07/94 19:05	1	0.001	0.001	0.002	3.899	0.49	0.00	4	15217842	0.49	757	89531
23rd St.	10/07/94 19:51	2	0.255	0.255	0.262	3.899	67.33	66.84	36367	15217842	0.49	2095	89531
23rd St.	10/07/94 21:26	3	0.379	0.472	0.487	3.899	15.95	15.47	224538	15217842	0.49	4860	89531
23rd St.	10/07/94 21:36	4	0.382	0.531	0.531	3.899	27.07	26.59	238502	15217842	0.49	5151	89531
23rd St.	10/07/94 21:42	5	0.351	0.554	0.565	3.899	28.72	28.24	248505	15217842	0.49	5325	89531
23rd St.	10/14/94 21:33	1	0.082	0.082	0.084	0.930	2.90	2.30	2773	1410867	0.60	1300	87128
23rd St.	10/15/94 01:35	2	0.087	0.343	0.344	0.930	27.36	26.76	240621	1410867	0.60	10041	87128
23rd St.	10/15/94 03:36	3	0.166	0.512	0.512	0.930	36.30	35.70	488681	1410867	0.60	14412	87128
23rd St.	10/15/94 05:03	4	0.169	0.641	0.641	0.930	51.64	51.02	741468	1410867	0.62	17571	87128
23rd St.	10/15/94 06:47	5	0.040	0.672	0.673	0.930	30.09	29.40	990120	1410867	0.69	21663	87128
23rd St.	10/15/94 10:50	6	0.031	0.756	0.756	0.930	9.47	8.62	1222330	1410867	0.85	32885	87128
23rd St.	11/05/94 00:15	1	0.218	0.264	0.249	1.111	20.09	19.24	2070	3842564	0.84	2018	70722
23rd St.	11/05/94 00:59	2	0.953	1.000	0.978	1.111	671.76	670.92	759449	3842564	0.84	4239	70722
23rd St.	11/05/94 01:21	3	1.095	1.142	1.100	1.111	603.55	602.69	1573555	3842564	0.86	5365	70722
23rd St.	11/05/94 01:44	4	1.111	1.158	1.111	1.111	494.52	493.64	2367407	3842564	0.88	6565	70722
23rd St.	11/05/94 02:34	5	0.604	1.158	1.111	1.111	130.80	129.88	3143695	3842564	0.92	9257	70722
23rd St.	11/05/94 14:03	6	0.000	1.158	1.111	1.111	2.46	1.02	3839911	3842564	1.44	57920	70722
23rd St.	01/12/95 18:08	1	0.252	0.271	0.271	0.874	2.98	1.93	17175	2843558	1.06	8133	97578
23rd St.	01/12/95 18:42	2	0.796	0.859	0.862	0.874	393.68	392.62	710096	2843558	1.06	10293	97578
23rd St.	01/12/95 18:46	3	0.802	0.865	0.865	0.874	300.84	299.78	790389	2843558	1.06	10548	97578
23rd St.	01/12/95 19:03	4	0.802	0.865	0.865	0.874	385.59	384.53	1061890	2843558	1.06	11628	97578
23rd St.	01/12/95 19:14	5	0.802	0.865	0.865	0.874	456.29	455.22	1367387	2843558	1.07	12330	97578
23rd St.	01/12/95 19:25	6	0.802	0.865	0.865	0.874	434.15	433.06	1674817	2843558	1.09	13043	97578
23rd St.	01/12/95 19:39	7	0.802	0.865	0.865	0.874	274.89	273.78	1963208	2843558	1.11	13968	97578
23rd St.	01/12/95 20:07	8	0.745	0.865	0.865	0.874	118.66	117.50	2258192	2843558	1.16	15879	97578
23rd St.	01/12/95 21:31	9	0.000	0.865	0.865	0.874	35.24	33.93	2555996	2843558	1.30	22090	97578

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L		Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L		NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
38th St.	10/20/93 02:20	1	1516		216	0.25	9.72	E1	1.76	2.10	1.26	17.70
38th St.	10/20/93 02:46	2	916		96	0.22	4.05	E1	2.86	1.19	0.95	16.20
38th St.	10/20/93 03:22	3	404		40	0.25	2.10	E1	2.53	0.63	0.54	12.10
38th St.	10/20/93 05:01	4	230		36	0.12	1.67	E1	2.28	0.60	0.46	13.60
38th St.	10/20/93 05:49	5	210		26	0.11	1.84	E1	5.61	0.53	0.45	11.70
38th St.	10/20/93 07:00	6	120		19	0.10	1.37	E1	1.59	0.36	0.33	10.80
38th St.	10/20/93 07:07	7	31		6	0.08	0.95	E1	1.86	0.26	0.25	9.80
38th St.	10/29/93 14:27	1	38		7	0.07	2.50	E1	4.94	0.28	0.27	7.11
38th St.	10/29/93 16:23	2	20		4	0.16	3.90	E1	6.08	0.36	0.33	12.80
38th St.	10/29/93 16:36	3	49		5	0.16	3.60	E1	5.62	0.42	0.35	11.90
38th St.	10/29/93 16:45	4	86		12	0.20	3.90	E1	13.80	0.54	0.36	15.70
38th St.	10/29/93 16:52	5	93		16	0.29	3.60	E1	5.61	0.58	0.47	24.10
38th St.	10/29/93 16:59	6	86		16	0.32	3.90	E1	3.98	0.63	0.53	24.00
38th St.	10/29/93 17:57	7	59		10	0.54	3.60	E1	1.87	0.46	0.37	22.20
38th St.	10/29/93 18:45	8	38		7	0.42	2.80	E1	1.28	0.35	0.31	17.40
38th St.	10/29/93 19:57	9	28		4	0.32	2.50	E1	0.93	0.31	0.27	15.30
38th St.	10/29/93 20:05	10	25		3	0.29	4.20	E1	1.03	0.35	0.31	15.50
38th St.	11/03/93 01:04	1	4	<	0.5	0.06	0.31		0.26	0.18	0.16	4.76
38th St.	11/03/93 04:57	2	36		12	0.05			0.12	0.33	0.27	16.20
38th St.	11/03/93 06:44	3	14		6	0.05	0.42		0.19	0.24	0.22	11.90
38th St.	11/03/93 08:05	4	10		6	0.04	0.42		0.19	0.19	0.19	10.80
38th St.	11/14/93 05:23	1	8		3	0.03	0.58		1.10	0.24	0.22	6.04
38th St.	11/14/93 07:59	2	19		6	0.12	1.38		1.20	0.38	0.31	9.96
38th St.	11/14/93 09:42	3	24		6	0.10	1.05		0.28	0.38	0.31	13.50
38th St.	11/16/93 07:55	1	5		2	0.04	0.34		0.80	0.19	0.15	3.65
38th St.	11/16/93 09:45	2	2	<	0.5	0.06	0.24		0.94	0.18	0.15	4.13
38th St.	11/16/93 10:18	3	2		1	0.06	0.22		0.90	0.16	0.15	5.33
38th St.	11/16/93 10:41	4	4		2	0.06	0.28		1.16	0.17	0.14	5.84
38th St.	11/16/93 11:07	5	2		1	0.07	0.23		0.53	0.19	0.14	5.52
38th St.	11/16/93 13:49	6	2	<	0.5	0.06	0.28		1.36	0.19	0.15	4.93

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
38th St.	12/13/93 00:50	1	12	6	0.06	2.00	0.49	0.12	0.10	3.25
38th St.	12/13/93 01:14	2	3	1	0.08	6.20	0.43	0.32	0.10	3.49
38th St.	12/17/93 08:44	1	2	1	0.09	0.33	1.05	0.56	0.38	4.29
38th St.	12/17/93 09:42	2	2	0.5	0.09	0.24	1.14	0.39	0.39	3.57
38th St.	01/20/94 19:51	1	38	7	0.13	1.00	1.30	0.28	0.24	3.32
38th St.	01/20/94 20:25	2	14	2	0.17	0.64	1.22	0.19	0.18	3.37
38th St.	01/20/94 21:03	3	82	19	0.20	1.34	1.06	0.41	0.28	5.92
38th St.	01/20/94 21:07	4	72	16	0.24	1.34	1.07	0.40	0.31	6.01
38th St.	01/20/94 22:32	5	131	25	0.25	1.44	0.56	0.50	0.36	7.28
38th St.	01/20/94 23:22	6	88	19	0.27	1.34	0.69	0.52	0.37	9.68
38th St.	01/21/94 12:23	7	30	6	0.19	1.11	0.96	0.32	0.28	8.26
38th St.	02/10/94 03:16	1	20	7	0.05	0.52	1.11	0.18	0.17	3.49
38th St.	02/10/94 11:09	2	15	4	0.13	0.37	0.70	0.29	0.23	8.62
38th St.	02/10/94 14:37	3	12	2	0.13	1.18	0.71	0.54	0.48	7.24
38th St	02/22/94 08:57	1	176	28	0.10	2.18	0.33	0.46	0.19	4.15
38th St.	02/22/94 09:21	2	128	22	0.10	2.04	0.31	0.38	0.19	4.02
38th St.	02/22/94 09:42	3	114	18	0.11	2.05	0.31	0.35	0.19	4.03
38th St.	02/22/94 10:14	4	112	20	0.10	1.97	0.34	0.36	0.16	3.96
38th St.	02/22/94 11:21	5	65	12	0.09	1.65	0.30	0.81	0.20	3.73
38th St.	02/22/94 14:42	6	23	4	0.06	0.75	0.38	0.19	0.15	3.62
38th St.	02/22/94 14:43	7	24	5	0.06	0.87	0.38	0.19	0.13	3.67
38th St.	02/22/94 14:48	8	29	6	0.06	1.36	0.39	0.26	0.22	3.88
38th St.	02/28/94 23:07	1	NS	NS	0.22	1.30	1.04	0.28	NS	NS
38th St.	03/01/94 05:49	2	528	96	0.27	4.45	0.50	0.78	0.23	19.50
38th St.	03/01/94 06:52	3	198	38	0.23	3.26	0.45	0.48	0.19	4.13
38th St.	03/01/94 11:44	4	133	23	0.14	2.01	0.53	0.48	0.24	4.16
38th St.	03/08/94 23:27	1	62	13	0.24	0.81	0.92	0.32	0.20	4.71
38th St.	03/09/94 00:05	2	976	172	0.47	5.70	0.57	1.52	0.34	11.60
38th St.	03/09/94 00:15	3	1686	304	0.52	5.55	0.44	1.97	0.27	13.70
38th St.	03/09/94 00:24	4	1316	264	0.49	4.82	0.47	1.61	0.28	11.50

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon; Tot. Mg/L
38th St.	03/09/94 00:34	5	876	136	0.39	3.53	0.46	1.21	0.18	9.30
38th St.	03/09/94 01:14	6	644	92	0.35	2.34	0.48	0.88	0.20	7.61
38th St.	03/09/94 02:49	7	230	50	0.30	1.53	0.47	0.58	0.17	11.30
38th St.	03/09/94 12:16	8	34	6	0.19	0.97	0.61	0.29	0.14	6.78
38th St.	03/09/94 14:00	9	13	2	0.16	0.56	0.68	0.16	0.13	6.75
38th St.	03/15/94 05:31	1	44	8	0.14	1.10	0.99	0.27	0.03	4.18
38th St.	03/15/94 07:18	2	225	44	0.19	0.60	0.47	0.44	0.08	6.83
38th St.	03/15/94 08:14	3	181	40	0.20	< 0.10	0.45	0.34	0.04	6.00
38th St.	03/15/94 10:45	4	67	20	0.18	1.10	0.47	0.21	0.03	5.04
38th St.	03/16/94 00:44	5	30	14	0.12	1.10	0.61	0.17	0.11	7.60
38th St.	04/06/94 16:43	1	44	14	0.17	1.81	0.89	0.40	0.16	12.20
38th St.	04/06/94 17:14	2	980	230	0.62	5.68	0.75	1.53	0.26	21.90
38th St.	04/06/94 17:28	3	808	160	0.69	4.53	0.68	1.43	0.19	17.70
38th St.	04/06/94 17:36	4	708	132	0.68	4.82	0.66	1.15	0.18	15.30
38th St.	04/06/94 17:56	5	560	96	0.64	3.89	0.64	0.99	0.29	15.70
38th St.	04/06/94 18:26	6	556	100	0.66	3.29	0.73	0.90	0.18	15.40
38th St.	04/06/94 21:48	7	156	44	0.62	1.86	0.83	0.46	0.23	16.40
38th St.	04/29/94 01:58	1	74	19	0.23	3.93	0.92	0.48	0.16	14.20
38th St.	04/29/94 02:58	2	1972	236	0.33	7.92	0.46	1.63	0.12	6.18
38th St.	04/29/94 03:58	3	876	92	0.34	2.67	0.48	0.96	0.13	6.44
38th St.	04/29/94 04:58	4	455	45	0.26	2.38	0.52	0.63	0.13	6.30
38th St.	04/29/94 05:58	5	192	23	0.26	2.07	0.55	0.53	0.16	8.14
38th St.	04/29/94 06:58	6	165	24	0.25	1.80	0.51	0.44	0.16	8.98
38th St.	04/29/94 07:50	7	48	7	LE	1.20	0.50	0.33	0.14	8.33
38th St.	04/29/94 08:50	8	57	8	LE	1.07	0.54	0.27	0.13	7.85
38th St.	04/29/94 09:50	9	40	14	LE	1.04	0.64	0.26	0.12	8.24
38th St.	04/29/94 10:50	10	38	7	LE	0.98	0.54	0.23	0.13	8.39
38th St.	04/29/94 11:50	11	35	6	LE	0.96	0.60	0.25	0.13	8.52
38th St.	04/29/94 12:50	12	30	7	LE	0.89	0.64	0.24	0.14	8.53
38th St.	05/13/94 13:32	1	46	10	0.21	1.09	0.83	0.32	0.21	7.98

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
38th St.	10/07/94 22:54	6	476	76	0.25	2.48	0.47	0.89	0.12	11.40
38th St.	10/15/94 07:45	1	21	4	0.07	0.78	1.24	0.15		
38th St.	10/16/94 04:25	1	33	5	0.07	0.70	1.79	0.13		
38th St.	10/16/94 14:19	2	40	8	0.10	0.91	2.76	0.19		
38th St.	10/16/94 22:26	3	33	5	0.05	0.81	2.38	0.24		
38th St.	10/17/94 00:38	4	32	6	0.08	1.25	1.52	0.19		
38th St.	10/17/94 02:50	5	16	4	0.12	0.96	1.52	0.18		
38th St.	10/18/94 15:23	1			0.10	4.83	1.39	1.64		
38th St.	10/18/94 15:40	2	866	120	0.08	3.45	2.88	1.01	< 0.02	3.75
38th St.	10/18/94 16:07	3	830	112	0.09	2.18	1.18	0.73	< 0.02	4.57
38th St.	10/18/94 19:02	4	235	37	0.13	1.10	1.10	0.34	0.02	5.74
38th St.	11/05/94 01:10	1			0.08	3.20	0.64	1.06		
38th St.	11/05/94 01:25	2	1232	320	0.12	2.80	0.32	1.24		5.58
38th St.	11/05/94 01:45	3	908	244	0.11	< 2.00	1.00	0.71	0.08	4.95
38th St.	11/05/94 02:22	4			< 0.02	4.34	0.43	2.28		
38th St.	11/05/94 02:26	5	264	78	0.09	< 2.00	0.35	0.89	0.08	4.88
38th St.	11/05/94 13:16	6	20	6	0.06	< 2.00	0.78	0.52		
38th St.	01/12/95 18:00	1	24	5	0.09	0.94	1.06	0.86	0.14	5.28
38th St.	01/12/95 18:46	2	785	120	0.13	4.64	0.34	1.96	0.08	10.20
38th St.	01/12/95 18:51	3	900	125	0.11	4.95	0.30	1.79	0.07	9.23
38th St.	01/12/95 18:57	4	1032	130	0.12	4.32	0.28	1.95	0.06	7.57
38th St.	01/12/95 19:05	5	1025	140	0.13	3.98	0.30	1.80	0.05	5.92
38th St.	01/12/95 19:12	6	1225	140	0.12	4.09	0.33	1.69	0.05	10.10
38th St.	01/12/95 19:22	7	1142	130	0.12	4.15	0.31	1.50	0.08	8.72
38th St.	01/12/95 19:36	8	889	98	0.12	3.45	0.32	1.33	0.08	5.27
23rd St.	09/26/93 14:37	1	71	16	0.17	0.82	0.56	0.43	0.43	11.60

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	10/20/93 01:06	1	142	26	0.09	2.01	0.51	0.54	0.38	4.55
23rd St.	10/20/93 02:05	2	454	92	0.24	5.87	0.96	1.26	0.94	18.20
23rd St.	10/20/93 02:30	3	838	160	0.26	8.74	1.12	1.67	1.21	20.00
23rd St.	10/20/93 03:07	4	656	86	0.21	4.50	0.58	1.12	0.88	15.40
23rd St.	10/20/93 04:37	5	262	40	0.13	2.85	0.45	0.67	0.57	11.10
23rd St.	10/20/93 05:19	6	170	22	0.10	1.79	0.26	0.60	0.50	10.80
23rd St.	10/20/93 06:19	7	134	14	0.08	1.50	0.33	0.50	0.45	10.20
23rd St.	10/20/93 08:01	8	70	10	0.06	1.08	0.38	0.39	0.37	12.60
23rd St.	10/29/93 13:53	1	6	2	1.07	4.50	2.07	0.23	0.23	4.04
23rd St.	10/29/93 15:29	2	108	23	1.25	1.10	2.35	0.55	0.43	18.90
23rd St.	10/29/93 16:16	3	134	27	NS	NS	2.30	NS	NS	NS
23rd St.	10/29/93 17:13	4	84	14	0.88	6.20	2.28	0.44	0.39	16.30
23rd St.	10/29/93 18:11	5	57	12	0.75	5.00	2.82	0.39	0.34	LE
23rd St.	10/29/93 18:26	6	LE	LE	0.63	4.50	5.10	0.40	0.34	LE
23rd St.	11/03/93 00:09	1	4	1	0.05	0.37	0.93	0.22	0.20	8.19
23rd St.	11/03/93 03:18	2	33	6	0.10	0.59	0.50	0.35	0.31	13.90
23rd St.	11/03/93 05:12	3	30	4	0.09	0.71	0.48	0.32	0.30	8.64
23rd St.	11/03/93 07:48	4	11	2	0.05	0.51	0.39	0.25	0.24	14.20
23rd St.	11/03/93 10:42	5	5	2	0.04	0.31	0.36	0.22	0.21	10.50
23rd St.	11/03/93 11:12	6	6	1	0.04	0.40	0.48	0.23	0.20	9.68
23rd St.	11/14/93 04:50	1	3	1	0.04	0.37	1.68	0.15	0.14	6.62
23rd St.	11/14/93 06:41	2	120	24	0.11	1.36	0.90	0.47	0.31	11.50
23rd St.	11/14/93 07:17	3	196	32	0.11	1.45	0.44	0.54	0.28	7.29
23rd St.	11/14/93 08:20	4	57	10	0.09	0.82	0.66	0.38	0.33	10.40
23rd St.	11/14/93 10:36	5	13	4	0.06	0.57	0.99	0.30	0.30	10.50
23rd St.	11/16/93 06:59	1	2	1	0.03	0.34	0.58	0.18	0.15	4.32
23rd St.	11/16/93 08:52	2	14	5	0.05	0.57	0.63	0.40	0.38	11.20
23rd St.	11/16/93 09:32	3	14	4	0.05	0.64	1.08	0.33	0.23	12.50
23rd St.	11/16/93 10:11	4	18	4	0.08	0.76	1.65	0.36	0.22	15.20
23rd St.	11/16/93 11:58	5	15	4	0.08	0.78	0.76	0.43	0.43	14.60

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	12/13/93 00:23	1	19	9	0.23	5.30	0.44	0.27	0.14	14.20
23rd St.	12/13/93 01:31	2	45	20	0.38	3.60	0.41	0.46	0.20	14.20
23rd St.	12/13/93 01:51	3	74	22	0.37	4.20	0.31	0.55	0.03	19.80
23rd St.	12/13/93 02:53	4	49	15	0.38	2.50	0.72	0.54	0.25	24.00
23rd St.	12/13/93 04:20	5	25	7	0.38	2.20	0.48	0.40	0.11	23.60
23rd St.	12/13/93 08:45	6	7	4	< 0.02	2.20	0.40	0.27	0.13	13.40
23rd St.	01/13/94 02:47	1	2	< 0.5	0.09	0.34	1.00	0.20	0.18	3.71
23rd St.	01/13/94 03:25	2	54	18	0.17	0.72	1.16	0.43	0.30	11.00
23rd St.	01/13/94 03:58	3	78	22	0.32	1.21	1.10	0.62	0.38	16.60
23rd St.	01/13/94 04:19	4	56	16	0.35	1.02	1.22	0.66	0.47	22.50
23rd St.	01/13/94 05:11	5	28	8	0.37	0.85	1.27	0.52	0.40	20.90
23rd St.	01/13/94 05:26	6	23	7	0.35	1.66	1.33	0.47	0.37	20.00
23rd St.	01/20/94 18:34	1	6	2	0.14	0.68	1.16	0.20	0.20	7.52
23rd St.	01/20/94 19:36	2	19	7	0.27	0.97	1.20	0.29	0.26	10.80
23rd St.	01/20/94 20:03	3	104	36	0.27	2.05	1.07	0.56	0.56	10.10
23rd St.	01/20/94 21:35	4	104	22	0.30	1.27	0.72	0.56	0.41	8.62
23rd St.	01/20/94 22:45	5	68	17	0.29	0.90	0.97	0.39	0.34	9.04
23rd St.	01/20/94 23:57	6	72	17	0.26	0.78	0.86	0.38	0.29	9.32
23rd St.	01/21/94 11:50	7	15	4	0.16	0.86	1.08	0.32	0.25	10.40
23rd St.	01/21/94 13:08	8	12	4	0.16	0.80	1.08	0.26	0.25	8.46
23rd St.	01/21/94 13:32	9	10	3	0.15	0.74	1.18	0.28	0.28	8.11
23rd St.	01/24/94 13:25	1	22	4	0.08	0.65	0.79	0.26	0.22	8.30
23rd St.	01/24/94 13:55	2	26	5	0.07	0.64	0.82	0.24	0.22	8.07
23rd St.	01/24/94 14:54	3	16	1	0.06	0.84	0.86	0.26	0.20	9.79
23rd St.	02/10/94 02:52	1	9	5	0.04	0.43	0.68	0.19	0.19	3.64
23rd St.	02/10/94 03:26	2	359	116	0.10	2.07	0.72	0.95	0.19	7.28
23rd St.	02/10/94 06:00	3	43	11	0.18	0.63	0.70	0.36	0.24	7.60
23rd St.	02/10/94 09:31	4	6	3	0.17	0.46	0.82	0.34	0.28	7.22
23rd St.	02/10/94 14:47	5	27	10	0.16	0.62	0.74	0.30	0.30	9.90
23rd St.	02/22/94 09:04	1	220	42	0.12	3.44	0.38	0.52	0.17	11.00

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	02/22/94 09:16	2	196	40	0.11	2.87	0.37	0.52	0.20	4.72
23rd St.	02/22/94 09:29	3	166	32	0.10	2.91	0.34	0.52	0.22	4.31
23rd St.	02/22/94 09:43	4	144	26	0.10	2.44	0.36	0.49	0.24	4.34
23rd St.	02/22/94 10:01	5	120	26	0.09	2.18	0.37	0.40	0.24	4.11
23rd St.	02/22/94 10:24	6	101	25	0.08	1.28	0.34	0.36	0.19	3.95
23rd St.	02/22/94 15:21	7	19	4	0.04	0.66	0.52	0.19	0.19	3.68
23rd St.	02/28/94 16:38	1	25	16	0.38	2.18	1.54	0.28	0.19	22.00
23rd St.	02/28/94 20:50	2	21	12	0.33	1.40	1.47	0.23	0.17	12.90
23rd St.	02/28/94 21:18	3	20	20	0.35	1.58	1.53	0.23	0.21	13.00
23rd St	03/01/94 05:11	4	1196	300	0.26	5.39	0.58	2.01	0.19	9.16
23rd St.	03/01/94 06:40	5	336	78	0.28	2.48	0.59	0.74	0.17	6.26
23rd St.	03/01/94 08:25	6	96	22	0.18	1.30	0.52	0.31	0.15	4.50
23rd St.	03/01/94 10:19	7	54	15	0.15	0.54	0.59	0.23	0.16	3.94
23rd St.	03/01/94 11:12	8	60	28	0.13	0.55	0.63	0.23	0.15	3.94
23rd St.	03/01/94 12:12	9	49	13	0.12	0.57	0.65	0.23	0.16	5.04
23rd St.	03/08/94 23:17	1	22	8	0.04	0.68	0.67	0.20	0.14	4.15
23rd St.	03/08/94 23:39	2	744	160	0.45	4.28	0.66	1.49	0.26	13.40
23rd St.	03/08/94 23:55	3	536	228	0.42	1.92	0.49	0.69	0.26	9.61
23rd St.	03/09/94 00:30	4	812	188	0.45	3.74	0.54	1.41	0.26	9.90
23rd St.	03/09/94 01:02	5	520	110	0.40	2.80	0.39	0.98	0.19	9.11
23rd St.	03/09/94 02:03	6	342	62	0.32	2.10	0.45	0.62	0.17	7.73
23rd St.	03/09/94 06:03	7	45	11	0.24	1.05	0.52	0.31	0.19	9.72
23rd St.	03/09/94 11:02	8	17	4	0.15	0.80	0.63	0.24	0.19	7.24
23rd St.	03/15/94 05:19	1	7	5	0.04	0.80	1.02	0.12	0.04	3.65
23rd St.	03/15/94 07:28	2	226	75	0.21	1.70	0.70	0.63	0.08	4.18
23rd St.	03/15/94 09:25	3	104	28	0.20	0.60	0.51	0.30	0.08	5.73
23rd St.	04/06/94 16:36	1	90	31	0.14	1.10	0.77	0.30	0.12	6.43
23rd St.	04/06/94 17:21	2	1230	270	0.77	7.70	1.04	2.16	0.36	31.20
23rd St.	04/06/94 17:34	3	1050	170	0.71	7.16	0.88	1.93	0.28	24.10
23rd St.	04/06/94 17:52	4	680	120	0.68	5.04	0.78	1.60	0.28	21.20

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	04/06/94 18:25	5	420	148	0.62	2.95	0.71	0.82	0.24	21.60
23rd St.	04/06/94 19:29	6	300	84	0.57	2.30	0.73	0.66	0.21	16.10
23rd St.	04/06/94 22:07	7	144	42	0.48	1.70	0.78	0.43	0.32	14.70
23rd St.	04/29/94 01:08	1	14	6	0.13	1.96	1.03	0.40	0.24	16.50
23rd St.	04/29/94 02:10	2	1620	316	0.48	10.90	0.62	2.46	0.22	12.80
23rd St.	04/29/94 02:26	3	528	114	0.37	6.06	0.57	1.14	0.22	12.80
23rd St.	04/29/94 02:49	4	1103	194	0.42	8.34	0.55	1.92	0.24	14.20
23rd St.	04/29/94 03:04	5	1512	220	0.44	7.78	0.47	1.91	0.18	10.50
23rd St.	04/29/94 10:00	6	85	13	LE	1.76	0.68	0.62	0.16	10.10
23rd St.	04/29/94 14:10	7	23	5	LE	0.93	0.68	0.23	0.13	9.91
23rd St.	05/13/94 13:16	1	310	98	0.03	1.96	0.90	0.46	0.24	8.56
23rd St.	05/13/94 14:18	2	1062	154	0.31	4.78	0.61	1.60	0.18	11.00
23rd St.	05/13/94 14:30	3	1070	162	0.28	5.65	0.53	1.65	0.22	11.00
23rd St.	05/13/94 14:44	4	1086	172	0.30	4.58	0.51	1.21	0.20	9.05
23rd St.	05/13/94 15:06	5	762	98	0.25	3.00	0.46	0.96	0.16	7.12
23rd St.	05/13/94 15:47	6	422	56	0.18	1.77	0.37	0.58	0.16	6.22
23rd St.	05/13/94 20:15	7	57	10	0.11	0.87	0.56	0.26	0.22	6.43
23rd St.	05/13/94 20:18	8	54	14	0.11	0.92	0.60	0.27	0.19	6.88
23rd St.	05/13/94 21:03	9	50	11	0.09	1.16	0.60	0.26	0.18	6.70
23rd St.	05/13/94 22:44	10	37	7	0.07	1.00	0.63	0.22	0.14	6.99
23rd St.	05/14/94 01:16	11	25	6	0.08	0.87	0.70	0.23	0.16	6.64
23rd St.	08/04/94 15:00	1			0.07	0.98	0.62	0.33		5.56
23rd St.	08/04/94 17:41	2			0.20	5.51	1.49	1.01		72.80
23rd St.	08/08/94 20:35	1	900	290	0.30	2.09	0.50	1.63	0.44	12.10
23rd St.	08/08/94 20:58	2	1233	420	0.50	5.90	0.90	3.02	0.47	30.90
23rd St.	08/08/94 21:24	3	2033	553	0.52	7.74	0.87	3.00	0.50	23.60
23rd St.	08/08/94 21:38	4	2127	467	0.48	6.52	0.84	2.98	0.63	23.40
23rd St.	08/08/94 21:57	5	1487	287	0.45	4.62	0.71	2.99	0.62	18.40
23rd St.	08/08/94 22:32	6	668	120	0.42	2.99	0.72	3.00	2.38	18.30
23rd St.	08/09/94 00:18	7	141	42	0.12	1.57	0.81	0.53	0.24	22.10

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	08/09/94 03:11	8	3252	952	0.19	3.08	0.40	1.66	0.18	19.70
23rd St.	08/09/94 03:16	9	2484	788	0.18	3.29	0.39	1.58	0.16	13.70
23rd St.	08/09/94 03:20	10	2056	624	0.17	3.03	0.42	1.46	0.19	6.88
23rd St.	08/09/94 03:24	11	3256	948	0.16	3.23	0.42	1.44	0.15	6.20
23rd St.	08/09/94 03:27	12	IS	IS	0.15	2.75	0.44	1.64		17.40
23rd St.	08/09/94 20:11	13	66	16	0.03	1.28	0.61	0.44	0.21	13.60
23rd St.	08/09/94 23:43	14	25	6	0.03	0.86	0.63	0.26		10.50
23rd St.	08/15/94 19:25	1	504	118	0.09	1.52	0.95	0.65	0.18	12.80
23rd St.	08/15/94 20:17	2	540	138	0.49	3.38	1.06	1.20	0.18	16.70
23rd St.	08/15/94 20:43	3	2464	380	0.38	4.93	0.76	1.61	0.13	12.00
23rd St.	08/15/94 21:01	4	1570	246	0.37	4.20	0.66	1.15	0.19	9.26
23rd St.	08/15/94 21:44	5	586	68	0.36	2.47	0.92	0.66	0.17	9.67
23rd St.	08/15/94 22:36	6	205	45	0.32	1.49	0.97	0.39	0.14	9.58
23rd St.	08/16/94 00:50	7	58	9	0.10	1.02	0.88	0.20	0.14	8.69
23rd St.	08/16/94 08:14	8	10	2	0.08	0.70	0.76	0.20		8.58
23rd St.	08/16/94 08:59	9	8	2	0.05	0.57	0.71	0.20		8.07
23rd St.	08/16/94 09:37	10	8	1	0.06	0.63	0.78	0.20		8.20
23rd St.	08/22/94 07:13	1	8	2	0.01	0.81	0.97	0.21		
23rd St.	08/22/94 09:14	2	35	8	0.13	1.06	1.09	0.25		
23rd St.	08/22/94 09:57	3	28	6	0.12	0.98	0.95	0.25		
23rd St.	08/22/94 14:06	4	20	6	0.01	0.85	0.88	0.23	0.18	
23rd St.	08/22/94 17:30	5	14	4	0.03	0.72	0.63	0.23		
23rd St.	09/08/94 02:27	1	6	3	0.03	0.63	0.69	0.25		4.35
23rd St.	09/08/94 07:57	2	18	7	0.03	1.40	0.98	0.30	0.20	17.20
23rd St.	09/08/94 08:14	3	2156	424	0.22	4.35	0.68	1.49	0.14	9.26
23rd St.	09/08/94 08:19	4	2880	836	0.19	4.00	0.58	1.94	0.41	7.25
23rd St.	09/08/94 08:22	5	2176	604	0.16	3.20	0.54	1.78	0.13	6.26
23rd St.	09/08/94 08:31	6	2100	272	0.18	4.21	0.65	1.79	0.16	7.04
23rd St.	09/08/94 11:01	7	135	18	0.13	2.12	0.75	1.22	0.16	6.26
23rd St.	09/08/94 17:00	8	16	3	0.07	0.77	0.65	0.26		6.36

Appendix E: Pollutant Concentrations for Water Quality Samples
Nutrients and Solids

Site	Date and Time	Sample Number	Suspended Solids, Tot. Mg/L	Suspended Solids, Vol. Mg/L	Ammonia Nitrogen Mg/L	Kjeldahl Nitrogen Mg/L	NO2 + NO3 Nitrogen Mg/L	Total Phosphorus Mg/L	Dissolved Phosphorus Mg/L	Organic Carbon, Tot. Mg/L
23rd St.	09/08/94 23:08	9	14	5	0.07	0.76	0.83	0.23		4.35
23rd St.	09/08/94 23:36	10	634	256	0.15	1.31	0.62	0.58	0.14	17.20
23rd St.	09/09/94 00:45	11	1258	258	0.15	2.04	0.78	0.80	0.15	9.26
23rd St.	09/09/94 01:56	12	186	43	0.10	1.02	0.65	0.32	0.10	7.25
23rd St.	10/07/94 19:05	1	285	57	0.63	4.40	1.85	1.32	0.20	48.70
23rd St.	10/07/94 19:51	2	141	29	0.60	3.93	1.94	0.80	0.32	49.10
23rd St.	10/07/94 21:26	3	529	99	0.44	3.50	0.98	1.65	0.20	15.40
23rd St.	10/07/94 21:36	4	488	90	0.40	3.76	0.98	1.92	0.16	16.60
23rd St.	10/07/94 21:42	5	537	105	0.32	3.62	0.44	2.00	0.16	12.40
23rd St.	10/14/94 21:33	1	21	8	0.18	2.21	1.55	2.58	0.13	10.80
23rd St.	10/15/94 01:35	2	28	6	0.14	0.95	1.37	0.24	0.17	
23rd St.	10/15/94 03:36	3	24	6	0.16	0.85	1.00	0.22	0.12	
23rd St.	10/15/94 05:03	4	25	6	0.12	0.89	1.85	0.21		
23rd St.	10/15/94 06:47	5	14	3	0.09	0.63	1.23	0.15		
23rd St.	10/15/94 10:50	6	8	1	0.05	0.53	1.06	0.12		
23rd St.	11/05/94 00:15	1	292	106	0.13	< 2.00	1.39	0.66	0.09	10.10
23rd St.	11/05/94 00:59	2	420	100	0.11	2.50	0.31	1.16	0.06	
23rd St.	11/05/94 01:21	3	522	140	0.11	2.50	0.33	0.80	0.13	6.50
23rd St.	11/05/94 01:44	4	610	102	0.11	< 2.00	0.28	0.88	0.06	4.94
23rd St.	11/05/94 02:34	5	281	49	0.09	< 2.00	0.30	0.53	0.08	4.53
23rd St.	11/05/94 14:03	6	10	4	0.04	LE	0.72	0.17		
23rd St.	01/12/95 18:08	1	7	2	0.05	0.64	1.14	0.22	0.08	6.11
23rd St.	01/12/95 18:42	2	510	95	0.20	2.32	0.56	0.66		
23rd St.	01/12/95 18:46	3	408	60	0.15	2.21	0.38	0.78	0.11	6.07
23rd St.	01/12/95 19:03	4	562	80	0.15	3.51	0.55	1.12	0.14	6.72
23rd St.	01/12/95 19:14	5	720	98	0.15	3.66	0.38	1.58	0.08	9.05
23rd St.	01/12/95 19:25	6	795	105	0.15	4.06	0.31	1.22	0.06	6.17
23rd St.	01/12/95 19:39	7	918	108	0.13	3.60	0.34	1.10	0.32	6.50
23rd St.	01/12/95 20:07	8	627	75	0.13	2.63	0.33	0.84	0.09	6.81
23rd St.	01/12/95 21:31	9	208	27	0.12	1.31	0.38	0.46	0.11	5.40

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
38th St.	10/20/93 02:20	1	28.0	380.0	> 120000	144000				
38th St.	10/20/93 02:46	2	20.0	187.0	> 120000	116000				
38th St.	10/20/93 03:22	3	13.0	70.0	> 120000	102000				
38th St.	10/20/93 05:01	4	13.0	75.0	> 120000	86000				
38th St.	10/20/93 05:49	5	13.0	72.0	> 120000	94000				
38th St.	10/20/93 07:00	6	10.0	52.0	> 120000	96000				
38th St.	10/20/93 07:07	7	8.0	43.0	> 120000	83000				
38th St.	10/29/93 14:27	1	4.0	28.0	167	667				
38th St.	10/29/93 16:23	2	< 12.0	46.0	12000	14000				
38th St.	10/29/93 16:36	3	< 12.0	50.0	9000	20000				
38th St.	10/29/93 16:45	4	26.0	67.0	11000	31000				
38th St.	10/29/93 16:52	5	28.0	97.0	35000	50000				
38th St.	10/29/93 16:59	6	28.0	99.0	37000	54000				
38th St.	10/29/93 17:57	7	20.0	86.0	50000	52000				
38th St.	10/29/93 18:45	8	17.0	77.0	30000	32000				
38th St.	10/29/93 19:57	9	21.0	65.0	17000	44000				
38th St.	10/29/93 20:05	10	15.0	64.0	14000	< 100				
38th St.	11/03/93 01:04	1	4.0	22.0	1333	3000				
38th St.	11/03/93 04:57	2	14.0	64.0	42000	46000				
38th St.	11/03/93 06:44	3	10.0	42.0	50000	63000				
38th St.	11/03/93 08:05	4	9.0	38.0	28000	40500				
38th St.	11/14/93 05:23	1	< 4.0	23.0	333	1000				
38th St.	11/14/93 07:59	2	8.0	57.0	53000	67000				
38th St.	11/14/93 09:42	3	12.0	61.0	83833	102000				
38th St.	11/16/93 07:55	1	3.0	9.0	667	1333				
38th St.	11/16/93 09:45	2	4.0	< 5.0	8000	8333				
38th St.	11/16/93 10:18	3	4.0	< 5.0	8500	10084				
38th St.	11/16/93 10:41	4	4.0	7.0	3667	7000				
38th St.	11/16/93 11:07	5	5.0	< 5.0	5667	10000				
38th St.	11/16/93 13:49	6	4.0	< 5.0	4000	3667				

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
38th St.	12/13/93 00:50	1	2.0	11.0	583	1000				
38th St.	12/13/93 01:14	2	3.0	12.0	500	1333				
38th St.	12/17/93 08:44	1	2.0	9.0	800	600				
38th St.	12/17/93 09:42	2	2.0	< 5.0	3200	2150				
38th St.	01/20/94 19:51	1	< 2.0	24.0	1143	3572				
38th St.	01/20/94 20:25	2	2.0	12.0	1428	3000				
38th St.	01/20/94 21:03	3	7.0	42.0	4000	20000				
38th St.	01/20/94 21:07	4	7.0	39.0	< 2000	12000				
38th St.	01/20/94 22:32	5	< 9.0	61.0	20000	36000				
38th St.	01/20/94 23:22	6	< 10.0	69.0	12000	28000				
38th St	01/21/94 12:23	7	< 5.0	37.0	90000	8000				
38th St.	02/10/94 03:16	1	> 2.0	19.0	572	2000				
38th St.	02/10/94 11:09	2	7.0	40.0	6000	10857				
38th St.	02/10/94 14:37	3	5.0	34.0	6428	5428				
38th St.	02/22/94 08:57	1	6.0	60.0	34000	96000				
38th St.	02/22/94 09:21	2	5.0	50.0	10000	88000				
38th St.	02/22/94 09:42	3	5.0	49.0	20000	72000				
38th St.	02/22/94 10:14	4	6.0	42.0	28000	86000				
38th St.	02/22/94 11:21	5	5.0	48.0	18000	44000				
38th St.	02/22/94 14:42	6	3.0	16.0	13333	15333				
38th St.	02/22/94 14:43	7	3.0	22.0	8000	14000				
38th St.	02/22/94 14:48	8	4.0	28.0	13333	14000				
38th St.	02/28/94 23:07	1	NS	29.0	NS	NS				
38th St.	03/01/94 05:49	2	7.0	110.0	12000	58000				
38th St.	03/01/94 06:52	3	6.0	87.0	12000	29000				
38th St	03/01/94 11:44	4	4.0	55.0	11333	12000				
38th St.	03/08/94 23:27	1	4.0	27.0	1000	8000				
38th St.	03/09/94 00:05	2	> 8.0	180.0	28000	86000				
38th St.	03/09/94 00:15	3	> 8.0	210.0	38000	142000				
38th St.	03/09/94 00:24	4	> 8.0	214.0	32000	194000				

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
38th St.	03/09/94 00:34	5	> 8.0	136.0	40000	202000				
38th St.	03/09/94 01:14	6	> 8.0	101.0	20000	192000				
38th St.	03/09/94 02:49	7	> 9.0	80.0	11000	90000				
38th St.	03/09/94 12:16	8	7.0	40.0	9000	35000				
38th St.	03/09/94 14:00	9	6.0	28.0	6000	21000				
38th St.	03/15/94 05:31	1	3.0	31.0	562	1250				
38th St.	03/15/94 07:18	2	8.0	71.0	7667	45250				
38th St.	03/15/94 08:14	3	6.0	52.0	5333	44500				
38th St.	03/15/94 10:45	4	8.0	28.0	7333	49250				
38th St.	03/16/94 00:44	5	4.0	34.0	2400	11233				
38th St.	04/06/94 16:43	1	16.0	119.0	173	22800				
38th St.	04/06/94 17:14	2	39.0	220.0	42000	314000				
38th St.	04/06/94 17:28	3	33.0	187.0	47636	140000				
38th St.	04/06/94 17:36	4	30.0	195.0	42000	122000				
38th St.	04/06/94 17:56	5	23.0	133.0	41000	149000				
38th St.	04/06/94 18:26	6	22.0	121.0	36000	99000				
38th St.	04/06/94 21:48	7	15.0	68.0	23234	88800				
38th St.	04/29/94 01:58	1	18.0	85.0	19636	23000	NR	NR	NR	NR
38th St.	04/29/94 02:58	2	< 21.0	218.0	142000	172000	NR	NR	NR	NR
38th St.	04/29/94 03:58	3	< 10.0	105.0	97500	108000	NR	NR	NR	NR
38th St.	04/29/94 04:58	4	6.0	50.0	75500	85636	NR	NR	NR	NR
38th St.	04/29/94 05:58	5	8.0	71.0	85000	69090	NR	NR	NR	NR
38th St.	04/29/94 06:58	6	7.0	67.0	70000	87636	NR	NR	NR	NR
38th St.	04/29/94 07:50	7	6.0	52.0	INF	> 667	NR	NR	NR	NR
38th St.	04/29/94 08:50	8	6.0	39.0	17200	81600	NR	NR	NR	NR
38th St.	04/29/94 09:50	9	6.0	43.0	35040	> 667	NR	NR	NR	NR
38th St.	04/29/94 10:50	10	6.0	35.0	26080	37760	NR	NR	NR	NR
38th St.	04/29/94 11:50	11	5.0	39.0	INF	56640	NR	NR	NR	NR
38th St.	04/29/94 12:50	12	4.0	39.0	INF	> 667	NR	NR	NR	NR
38th St.	05/13/94 13:32	1	8.0	41.0	IS	IS	< 0.5	< 2	22	25

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
38th St.	05/13/94 14:24	2	22.0	212.0	IS	IS	1.0	28	165	356
38th St.	05/13/94 14:38	3	< 20.0	211.0	IS	IS	1.8	66	145	324
38th St.	05/13/94 14:55	4	< 20.0	126.0	IS	IS	0.6	64	255	228
38th St.	05/13/94 15:12	5	< 12.0	127.0	IS	IS	0.7	10	65	164
38th St.	05/13/94 15:48	6	< 12.0	76.0	IS	IS	1.0	68	35	132
38th St.	05/13/94 16:44	7	< 12.0	77.0	IS	IS	< 0.5	4	24	69
38th St.	05/13/94 18:18	8	< 8.0	51.0	IS	IS	< 0.5	6	16	52
38th St.	05/14/94 00:14	9	< 8.0	23.0	IS	IS	< 0.5	< 2	3	53
38th St.	08/08/94 20:37	1	8.0	118.0	3000	3000	< 1.0	7	7	43
38th St.	08/09/94 20:01	2	7.0	53.0	INF	470000	< 0.5	6	14	48
38th St.	08/15/94 20:01	1	4.0	38.0	10909	5000	< 1.0	4	3	6
38th St.	08/15/94 20:26	2	21.0	164.0	180000	220000	2.0	39	161	298
38th St.	08/15/94 20:36	3	16.0	147.0	152000	183636	1.0	36	149	278
38th St.	08/15/94 20:47	4	15.0	135.0	75455	136364	6.0	28	111	223
38th St.	08/15/94 21:03	5	12.0	92.0	79091	120000	< 1.0	20	66	156
38th St.	08/15/94 21:41	6	10.0	72.0	120000	111818	< 1.0	15	32	92
38th St.	08/22/94 08:56	1		< 5.0	10909	21818	< 0.5	< 2	< 2	21
38th St.	08/22/94 09:29	2	> 6.0	15.0	57000	52000	< 0.5	4	2	20
38th St.	08/22/94 11:44	3	8.0	24.0	280000	100000	< 0.5	4	6	29
38th St.	08/22/94 14:26	4		11.0	120000	47000	< 0.5	2	2	14
38th St.	09/14/94 16:19	1	3.0	29.0	13636	1000	< 0.5	2	12	
38th St.	09/14/94 18:58	2	11.0	68.0	240000	114545	< 0.5	7	48	
38th St.	09/14/94 19:24	3	9.0	58.0	230000	114545	< 0.5	7	40	
38th St.	09/14/94 20:18	4	8.0	50.0	220000	100909	< 0.5	6	40	
38th St.	09/14/94 21:37	5	6.0	40.0	225000	86272	< 0.5	4	24	
38th St.	10/07/94 19:59	1		25.6						
38th St.	10/07/94 20:32	2	9.0	46.8						
38th St.	10/07/94 22:21	3	31.0	144.0						
38th St.	10/07/94 22:35	4	8.0	132.0						
38th St.	10/07/94 22:46	5	16.0	84.5						

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
38th St.	10/07/94 22:54	6	13.0	94.4						
38th St.	10/15/94 07:45	1		29.0						
38th St.	10/16/94 04:25	1		29.0						
38th St.	10/16/94 14:19	2		37.0						
38th St.	10/16/94 22:26	3		31.0						
38th St.	10/17/94 00:38	4		41.0						
38th St.	10/17/94 02:50	5		37.0						
38th St.	10/18/94 15:23	1		133.0						
38th St.	10/18/94 15:40	2	10.0	61.2						
38th St.	10/18/94 16:07	3	11.0	67.3						
38th St.	10/18/94 19:02	4	1.9	32.5						
38th St.	11/05/94 01:10	1		96.0						
38th St.	11/05/94 01:25	2	< 9.0	110.0						
38th St.	11/05/94 01:45	3	8.0	63.0						
38th St.	11/05/94 02:22	4		159.0						
38th St.	11/05/94 02:26	5	5.0	39.0						
38th St.	11/05/94 13:16	6	3.0	22.0						
38th St.	01/12/95 18:00	1	2.0	< 5.0	153000	76000				
38th St.	01/12/95 18:46	2	18.0	139.0	39000	87000				
38th St.	01/12/95 18:51	3	18.0	168.0	27000	93000				
38th St.	01/12/95 18:57	4	18.0	209.0	60000	212000				
38th St.	01/12/95 19:05	5	27.0	157.0	66000	240000				
38th St.	01/12/95 19:12	6	18.0	185.0	54000	188000				
38th St.	01/12/95 19:22	7	17.0	165.0	54000	308000				
38th St.	01/12/95 19:36	8	14.0	181.0	29000	126000				
23rd St.	09/26/93 14:37	1	23.0	34.0	5454	9091	< 5.0	185	18	< 60

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	10/20/93 01:06	1	6.0	63.0	2000	2000				
23rd St.	10/20/93 02:05	2	22.0	231.0	64000	102000				
23rd St.	10/20/93 02:30	3	28.0	276.0	73333	158000				
23rd St.	10/20/93 03:07	4	19.0	181.0	134000	140000				
23rd St.	10/20/93 04:37	5	15.0	271.0	19333	118000				
23rd St.	10/20/93 05:19	6	< 15.0	70.0	32000	150000				
23rd St.	10/20/93 06:19	7	< 15.0	69.0	42000	100000				
23rd St.	10/20/93 08:01	8	< 15.0	37.0	38000	102000				
23rd St.	10/29/93 13:53	1	< 3.0	16.0	15000	2000				
23rd St.	10/29/93 15:29	2	18.0	86.0	77000	32000				
23rd St.	10/29/93 16:16	3	19.0	NS	50000	67000				
23rd St.	10/29/93 17:13	4	14.0	74.0	61000	36000				
23rd St.	10/29/93 18:11	5	16.0	57.0	56000	28000				
23rd St.	10/29/93 18:26	6	18.0	70.0	47000	30000				
23rd St.	11/03/93 00:09	1	5.0	31.0	44000	< 1000				
23rd St.	11/03/93 03:18	2	13.0	52.0	< 1000	70000				
23rd St.	11/03/93 05:12	3	8.0	40.0	18167	48000				
23rd St.	11/03/93 07:48	4	11.0	48.0	23333	44000				
23rd St.	11/03/93 10:42	5	7.0	38.0	22000	27000				
23rd St.	11/03/93 11:12	6	7.0	36.0	22000	21000				
23rd St.	11/14/93 04:50	1	< 15.0	21.0	3667	1000				
23rd St.	11/14/93 06:41	2	20.0	93.0	152000	115000				
23rd St.	11/14/93 07:17	3	< 15.0	108.0	104333	102000				
23rd St.	11/14/93 08:20	4	< 12.0	69.0	89833	87500				
23rd St.	11/14/93 10:36	5	< 12.0	42.0	103333	60000				
23rd St.	11/16/93 06:59	1	< 3.0	6.0	333	< 500				
23rd St.	11/16/93 08:52	2	> 12.0	34.0	11333	27250				
23rd St.	11/16/93 09:32	3	14.0	41.0	113000	49750				
23rd St.	11/16/93 10:11	4	> 16.0	58.0	35000	51500				
23rd St.	11/16/93 11:58	5	> 16.0	52.0	64000	52500				

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	12/13/93 00:23	1	16.0	54.0	46500	13700				
23rd St.	12/13/93 01:31	2	23.0	81.0	78000	57000				
23rd St.	12/13/93 01:51	3	22.0	90.0	129000	127000				
23rd St.	12/13/93 02:53	4	28.0	95.0	189000	161000				
23rd St.	12/13/93 04:20	5	21.0	76.0	160000	140000				
23rd St.	12/13/93 08:45	6	12.0	50.0	47000	65000				
23rd St.	01/13/94 02:47	1	< 24.0	10.0	500	13928				
23rd St.	01/13/94 03:25	2	< 15.0	62.0	20000	24000				
23rd St.	01/13/94 03:58	3	< 24.0	93.0	92000	50000				
23rd St.	01/13/94 04:19	4	< 24.0	85.0	106000	48000				
23rd St.	01/13/94 05:11	5	< 17.0	63.0	172000	94000				
23rd St.	01/13/94 05:26	6	< 15.0	62.0	162000	62000				
23rd St.	01/20/94 18:34	1	4.0	14.0	2286	6000				
23rd St.	01/20/94 19:36	2	6.0	36.0	8000	8000				
23rd St.	01/20/94 20:03	3	12.0	70.0	38000	26000				
23rd St.	01/20/94 21:35	4	8.0	52.0	48000	58000				
23rd St.	01/20/94 22:45	5	8.0	69.0	6000	28000				
23rd St.	01/20/94 23:57	6	7.0	62.0	8000	22000				
23rd St.	01/21/94 11:50	7	5.0	28.0	244000	16000				
23rd St.	01/21/94 13:08	8	4.0	28.0	316000	14000				
23rd St.	01/21/94 13:32	9	4.0	20.0	242000	8000				
23rd St.	01/24/94 13:25	1	4.0	35.0	4000	52000				
23rd St.	01/24/94 13:55	2	3.0	34.0	4000	42000				
23rd St.	01/24/94 14:54	3	4.0	42.0	4000	24000				
23rd St.	02/10/94 02:52	1	2.0	18.0	3143	286				
23rd St.	02/10/94 03:26	2	> 7.0	132.0	14000	24000				
23rd St.	02/10/94 06:00	3	7.0	42.0	78500	41750				
23rd St.	02/10/94 09:31	4	5.0	27.0	19500	26000				
23rd St.	02/10/94 14:47	5	7.0	40.0	26000	412000				
23rd St.	02/22/94 09:04	1	6.0	70.0	28000	92000				

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	02/22/94 09:16	2	6.0	53.0	28000	98000				
23rd St.	02/22/94 09:29	3	5.0	52.0	32000	62000				
23rd St.	02/22/94 09:43	4	5.0	52.0	30000	74000				
23rd St.	02/22/94 10:01	5	5.0	47.0	28000	62000				
23rd St.	02/22/94 10:24	6	5.0	50.0	24000	76000				
23rd St.	02/22/94 15:21	7	3.0	22.0	6286	11000				
23rd St.	02/28/94 16:38	1	> 9.0	56.0	10000	3143				
23rd St.	02/28/94 20:50	2	7.0	45.0	22250	12000				
23rd St.	02/28/94 21:18	3	9.0	46.0	20500	13500				
23rd St.	03/01/94 05:11	4	8.0	326.0	106000	114000				
23rd St.	03/01/94 06:40	5	7.0	140.0	16000	74000				
23rd St.	03/01/94 08:25	6	7.0	48.0	15333	29000				
23rd St.	03/01/94 10:19	7	7.0	26.0	13333	18000				
23rd St.	03/01/94 11:12	8	3.0	28.0	10000	18000				
23rd St	03/01/94 12:12	9	3.0	22.0	2667	15333				
23rd St.	03/08/94 23:17	1	3.0	24.0	500	1000				
23rd St.	03/08/94 23:39	2	> 9.0	172.0	66000	194000				
23rd St.	03/08/94 23:55	3	> 9.0	101.0	60000	69000				
23rd St.	03/09/94 00:30	4	> 9.0	145.0	54000	92000				
23rd St.	03/09/94 01:02	5	> 9.0	116.0	28000	68000				
23rd St.	03/09/94 02:03	6	> 8.0	69.0	11000	54000				
23rd St.	03/09/94 06:03	7	> 9.0	40.0	12000	82000				
23rd St.	03/09/94 11:02	8	6.0	30.0	65000	16000				
23rd St.	03/15/94 05:19	1	2.0	14.0	1000	1571				
23rd St	03/15/94 07:28	2	> 8.0	86.0	27250	65000				
23rd St	03/15/94 09:25	3	7.0	46.0	13500	47375				
23rd St.	04/06/94 16:36	1	11.0	41.0	2200	3350				
23rd St.	04/06/94 17:21	2	60.0	331.0	62000	182000				
23rd St.	04/06/94 17:34	3	47.0	246.0	58000	286000				
23rd St.	04/06/94 17:52	4	33.0	212.0	40500	150500				

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	04/06/94 18:25	5	23.0	125.0	22000	128000				
23rd St.	04/06/94 19:29	6	18.0	90.0	35000	153000				
23rd St.	04/06/94 22:07	7	14.0	63.0	24000	82500				
23rd St.	04/29/94 01:08	1	6.0	57.0	174000	48000	NR	NR	NR	NR
23rd St.	04/29/94 02:10	2	< 46.0	481.0	284000	160000	NR	NR	NR	NR
23rd St.	04/29/94 02:26	3	19.0	171.0	137000	164000	NR	NR	NR	NR
23rd St.	04/29/94 02:49	4	26.0	300.0	INF	260000	NR	NR	NR	NR
23rd St.	04/29/94 03:04	5	< 27.0	290.0	INF	260000	NR	NR	NR	NR
23rd St.	04/29/94 10:00	6	5.0	75.0	53000	204000	NR	NR	NR	NR
23rd St.	04/29/94 14:10	7	5.0	32.0	INF	> 667	NR	NR	NR	NR
23rd St.	05/13/94 13:16	1	6.0	46.0	IS	IS	0.5	194	113	146
23rd St.	05/13/94 14:18	2	18.0	206.0	IS	IS	0.8	44	178	304
23rd St.	05/13/94 14:30	3	16.0	220.0	IS	IS	0.8	14	203	304
23rd St.	05/13/94 14:44	4	13.0	191.0	IS	IS	0.8	34	118	256
23rd St.	05/13/94 15:06	5	11.0	126.0	IS	IS	0.8	64	158	192
23rd St.	05/13/94 15:47	6	< 6.0	74.0	IS	IS	< 0.5	32	63	100
23rd St.	05/13/94 20:15	7	< 6.0	39.0	IS	IS	< 0.5	30	11	35
23rd St.	05/13/94 20:18	8	< 5.0	36.0	IS	IS	< 0.5	169	12	25
23rd St.	05/13/94 21:03	9	5.0	36.0	IS	IS	< 0.5	26	10	23
23rd St.	05/13/94 22:44	10	IS	37.0	IS	IS	< 0.5	354	8	31
23rd St.	05/14/94 01:16	11	IS	37.0	IS	IS	< 0.5	30	7	22
23rd St.	08/04/94 15:00	1		17.9			< 1.0	72	52	201
23rd St.	08/04/94 17:41	2		256.0			< 1.0	57	36	185
23rd St.	08/08/94 20:35	1	28.0	95.0	51000	6364	2.0	444	139	362
23rd St.	08/08/94 20:58	2	> 37.0	266.0	2E+06	560000	1.0	63	146	379
23rd St.	08/08/94 21:24	3	37.0	216.0	420000	210000	2.0	59	146	355
23rd St.	08/08/94 21:38	4	35.0	211.0	220000	220000	1.0	47	158	327
23rd St.	08/08/94 21:57	5	28.0	179.0	300000	123636	1.0	51	103	261
23rd St.	08/08/94 22:32	6	22.0	147.0	245000	110909	< 1.0	29	59	174
23rd St.	08/09/94 00:18	7	10.0	60.0	310000	67000	< 1.0	20	18	57

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	08/09/94 03:11	8	16.0	143.0	225455	93000	1.0	69	135	262
23rd St.	08/09/94 03:16	9	11.0	167.0	48000	34000	< 1.0	50	134	241
23rd St.	08/09/94 03:20	10	6.0	93.0	66364	76000	< 1.0	36	109	202
23rd St.	08/09/94 03:24	11	11.0	106.0	54000	116364	< 1.0	35	105	182
23rd St.	08/09/94 03:27	12	14.0	97.0	43000	91000	< 1.0	32	104	212
23rd St.	08/09/94 20:11	13	7.0	68.0	90000	78000	< 0.5	12	20	55
23rd St.	08/09/94 23:43	14	4.0	46.0	100000	69000	< 0.5	6	4	24
23rd St.	08/15/94 19:25	1	10.0	46.0	14545	5000	< 1.0	68	37	94
23rd St.	08/15/94 20:17	2	22.0	136.0	90000	130000	5.0	34	107	232
23rd St.	08/15/94 20:43	3	23.0	210.0	202727	290000	1.0	39	188	304
23rd St.	08/15/94 21:01	4	14.0	155.0	90000	127273	1.0	30	137	234
23rd St.	08/15/94 21:44	5	16.0	88.0	130000	100000	< 1.0	18	53	117
23rd St.	08/15/94 22:36	6	10.0	61.0	135000	105909	< 1.0	12	28	67
23rd St.	08/16/94 00:50	7	6.0	84.0	79091	620000	< 1.0	12	9	30
23rd St.	08/16/94 08:14	8	4.0	34.0	60000	31000	< 1.0	13	4	17
23rd St.	08/16/94 08:59	9	4.0	38.0	70000	57000	< 1.0	16	7	15
23rd St.	08/16/94 09:37	10	3.0	38.0	50000	32000	< 1.0	16	5	15
23rd St.	08/22/94 07:13	1		14.0	24000	5455	< 0.5	17	< 2	18
23rd St.	08/22/94 09:14	2	10.0	30.0	320000	200000	< 0.5	10	4	37
23rd St.	08/22/94 09:57	3	10.0	28.0	350000	110000	< 0.5	11	6	34
23rd St.	08/22/94 14:06	4	7.0	33.0	180000	78000	< 0.5	6	3	38
23rd St.	08/22/94 17:30	5		54.0			< 0.5	7	< 2	13
23rd St.	09/08/94 02:27	1	< 17.0	13.0	< 1000	< 1000	< 0.5	8	8	23
23rd St.	09/08/94 07:57	2	11.0	60.0	140000	33000	< 0.5	12	12	38
23rd St.	09/08/94 08:14	3	18.0	155.0	90000	157273	0.8	12	136	252
23rd St.	09/08/94 08:19	4	15.0	115.0	74545	126364	1.0	10	128	246
23rd St.	09/08/94 08:22	5	11.0	120.0	58000	150000	0.7	10	128	216
23rd St.	09/08/94 08:31	6	14.0	136.0	90000	126364	0.6	10	88	216
23rd St.	09/08/94 11:01	7	6.0	66.0	82727	61000	< 0.5	2	16	
23rd St.	09/08/94 17:00	8	4.0	23.0	100909	54000	< 0.5	4	4	

Appendix F: Pollutant Concentrations for Water Quality Samples
BOD, COD, Fecals and Metals

Site	Date and Time	Sample Number	Biochemical Oxygen Dem. Mg/L	Chemical Oxygen Dem. Mg/L	Fecal Coliform Col./100 Ml	Fecal Streptococci Col./100 Ml	Total Cadmium Ug/L	Total Copper Ug/L	Total Lead Ug/L	Total Zinc Ug/L
23rd St.	09/08/94 23:08	9	3.0	24.0	89091	27000	< 0.5	4	3	
23rd St.	09/08/94 23:36	10	6.0	51.0	75454	89000	0.5	5	36	
23rd St.	09/09/94 00:45	11	9.0	76.0	94545	83000	< 0.5	10	89	
23rd St.	09/09/94 01:56	12	6.0	42.0	61818	84500	< 0.5	6	60	
23rd St.	10/07/94 19:05	1	41.0	187.0						
23rd St.	10/07/94 19:51	2	41.0	187.0						
23rd St.	10/07/94 21:26	3	24.0	133.0						
23rd St.	10/07/94 21:36	4	20.0	129.0						
23rd St.	10/07/94 21:42	5	15.0	143.0						
23rd St.	10/14/94 21:33	1	9.0	75.0						
23rd St.	10/15/94 01:35	2	8.0	49.0						
23rd St.	10/15/94 03:36	3	8.0	55.0						
23rd St.	10/15/94 05:03	4	7.0	43.0						
23rd St.	10/15/94 06:47	5	5.0	34.0						
23rd St.	10/15/94 10:50	6		32.0						
23rd St.	11/05/94 00:15	1	13.0	90.0						
23rd St.	11/05/94 00:59	2	6.0	64.0						
23rd St.	11/05/94 01:21	3	8.0	62.0						
23rd St.	11/05/94 01:44	4	6.0	52.0						
23rd St.	11/05/94 02:34	5	5.0	29.0						
23rd St.	11/05/94 14:03	6	2.0	14.0						
23rd St.	01/12/95 18:08	1	3.0	< 5.0	6200	2800				
23rd St.	01/12/95 18:42	2	8.0	93.0						
23rd St.	01/12/95 18:46	3	10.0	98.0	69000	99000				
23rd St.	01/12/95 19:03	4	11.0	127.0	51000	123000				
23rd St.	01/12/95 19:14	5	16.0	149.0	28000	158000				
23rd St.	01/12/95 19:25	6	14.0	159.0	57000	100000				
23rd St.	01/12/95 19:39	7	15.0	171.0	50000	216000				
23rd St.	01/12/95 20:07	8	10.0	94.0	25000	168000				
23rd St.	01/12/95 21:31	9	7.0	62.0	25500	156000				